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AUTHOR Zuckerman, Carl B.; And Others
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ABSTRACT

An experiment was designed to compare the value of the Skinner Teaching Machine with more traditional teaching methods and to compare various means of presenting material via the teaching machine. Material from the United States Navy Basic Electricity course was programed into three series of items: one completion, one multiple choice, and one true-false. Each series was presented in a logical order and in a random sequence. In a supplementary experiment, the completion items were presented on prompting cards to compare the machine with this simpler device. Exams were administered before and after the lessons, and statistical analysis of the results revealed no significant difference in learning between random and sequenced presentation, between the different kinds of items, or between the teaching machine and prompting card presentation. A subsequent experiment compared the effects of the machine with the lecture method and textbooks. (Author/EMH)

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RESEARCH IN THE AUTOMATION OF TEACHING

Prepared by:

Carl B. Zuckerman
George R. Marshall
Sanford Groesberg
Department of Psychology
Brooklyn College
Contract N61339-661

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ABSTRACT

RESEARCH IN THE AUTOMATION OF TEACHING

The present research was designed to investigate the value of the Skinner Teaching Machine as compared with more traditional teaching methods and to compare different means of presenting material to be learned in the machine.

Material from the U. S. Navy Basic Electricity course was used. For the first experiment, material was programmed into three series of items: one of completion, one of multiple-choice and one of true-false items. Each series was presented in a logical order and in a random sequence. Six groups of subjects were used, one for each kind of presentation (i.e., Random Completion, Sequential, True-False, etc.). In a supplementary experiment, the completion items were presented on prompting cards to compare the machine with this simpler device. Examinations were administered before and after the learning session.

Statistical analysis of the results revealed no significant difference between random and sequential presentation, between the different kinds of items or between machine and prompting card learning.

In later experiments, a group of subjects learned the same material by means of a lecture presentation and another group by reading the text. Both groups received the same examination as those in the first experiment. The text group did significantly better than the machine group and better than the lecture group. The lecture group did significantly better than the machine group.

In addition to the above experiments, the attitudes of the subjects toward machine learning were obtained by means of a questionnaire.

Recommendations are made on the basis of this research.

FOREWORD

Purpose

Proper training and the use of training equipment are important contributions to successful performance of a given task. In the U. S. Navy training programs deserve particular attention in view of the limited time available for training and the complexity of the tasks to be performed.

The concept of teaching machines has considerable potential value in such training programs. As a result, a study was devised to investigate the mode of response to be used in teaching machines, the effect of random versus sequential presentation of material, and an evaluation of the teaching machine technique as compared with the more traditional manner of presentation.

Results

The results of this study can be summarized as follows:

1. Of the typical three modes of responding, i.e., true-false, multiple-choice, and completion, it was found that true-false was the least efficient. Although there was no significant difference between completion and multiple-choice, the direction of the difference favored the completion type of item.

2. When comparing programs of basic electricity with 60 items or less, there was no significant difference between random or sequential presentation.

3. The importance of programming was demonstrated when a comparison was made among four methods of presentation, i.e., programmed lecture, programmed text, programmed booklet, and a Skinner type teaching machine. Of these four methods the programmed text was most efficient, the lecture next, the programmed booklet third, and the machine presentation fourth.

Implications

This study emphasizes the importance of programming. The use of a machine, as such, is only a helpful adjunct to the successful presentation of well-programmed material. Moreover, the constructed type of response in an incremental manner is more advantageous for efficient learning than the true-false type of response.

Consequently, for Navy utilization of teaching machines careful consideration should be made as to whether or not to use programmed books or machines as such. In any case, careful consideration must be given to the programming of subject matter material to insure the most efficient learning.

Clayton K Bishop
Clayton K. Bishop, Ph.D.
Information Systems Branch

James J Regan
James J. Regan, Ph.D.
Head, Systems Psychology Division

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RECOMMENDATIONS

1. In comparison to multiple-choice and completion items programmed for the teaching machine, true-false items give rise to the least efficient program. It is therefore recommended that true-false items not be used. Further studies are required to determine the relative efficacy of multiple-choice and completion items for programs of more than sixty items.

2. In programs of sixty items or less, the order of presentation of items (i.e., whether sequential or random) has no determinable effect on the amount learned. Thus it is recommended that where only short learning sessions on the teaching machine are required the programmer need not be too concerned with the sequence of item presentation. It is also recommended that further studies be conducted to compare the effect of random or sequential order on learning as the number of programmed items increases.

3. The use of more traditional teaching methods (text and lecture) should not be discarded in favor of mechanical self-instructional devices.

4. If an incremental type, mechanical self-instructional device is desired, the use of a simpler and less expensive method such as prompting cards is recommended.

5. Within the limits of the experiment, there is no determinable relationship between the number of errors subjects made in the course of learning the material and examination scores. It is recommended that the number of errors should not be used as an index of what has been learned. Trainees, therefore, should not be eliminated from a course of training which uses teaching machines solely on the basis of their learning errors.

6. In the present study, no relationship was found between subjects' favorable or unfavorable attitudes to teaching machines and the amount learned. It is recommended, however, that further studies be made relating mechanical presentation of material and student attitude using longer programs and/or different subject matter.

7. A strong relationship was found to exist between the subject's estimate of his knowledge of electrical terms and symbols and familiarity with electricity as measured by an examination. As a simple way of determining recruits' knowledge of electricity it is recommended that a brief check list of electrical terms and symbols be presented.

8. The analysis of course content in order to program for the teaching machine appears to be of benefit in the preparation of lecture and text material. It is recommended, therefore, that instructors be required to program sections of the electricity course.

9. a. There is some suggestive evidence that, at the termination of the teaching machine session, an instructor by confirming and/or reassuring the subject that the information in the machine is dependable might significantly improve the application of material learned in the machine to a test of achievement. In other words, even a brief personal contact between the learner and a teacher might strengthen the efficacy of the teaching machine.

b. A study should be conducted relating amount of learning and time spent in using the teaching machine.

c. The relative effectiveness of machines which permit subjects to return to any item regardless of the previous accuracy of the response should be compared with the present teaching machine technique in which items once answered correctly cannot be reviewed.

d. All the comparisons made in this report are based on immediate recall. Studies should be conducted to determine whether there is differential effectiveness when delayed measures of retention are employed.

e. Subjects seem to be motivated to give a correct answer rather than to understand the content of the item. They appear to pay little or no attention to information in the item which is not required to answer the item. Thus items must be constructed so that the subject is required to utilize all the information in the item in order to make the correct response.

BRIEF OF STUDY

In recent years there has been a great deal of interest in developing more efficient methods for presenting material to be learned. Professor B.F. Skinner of Harvard University has developed a machine "teacher" and has aroused enthusiasism for automated (i.e., self-instructional) methods of teaching (Skinner, 1958). According to Skinner, the efficiency of learning is increased with the use of the teaching machine. With this device material is presented in an incremental fashion (i.e., small steps), and the student is able to check the correctness of his answer immediately.

Material to be presented in the Skinner machine must be programmed - i.e., course content is broken down into separate statements which are typed on a disc and exposed in the machine one at a time. The usual item is a statement which must be completed by one or several words. The subject reads the item and writes an answer on a tape placed next to the window through which the item is exposed. He then presses a lever which acts so as to expose the correct answer in the machine. At the same time, the subject's answer moves up under a plastic cover so that he cannot change it. The subject compares his answer to that exposed in the machine. If he is correct, he pushes the lever over to the right and then down. This ensures that this item will not reappear. If he is wrong, he pushes the lever straight down so that the item missed reappears later on. In both cases, lever movement also leads to the exposure of the next item. When the subject has gone through all the items on the disc the machine presents again only those items which he had not answered correctly. In this way the subject goes through the material on a disc until he has answered all the items correctly.

If the programming of the material is adequately done, no instructor is required. This does not mean that instructors will be supplanted by machines. Rather, the student will be able to acquire a good deal of information by himself, thus allowing the instructor to concentrate on developing the student's understanding of the course content. The question arises, however, whether the information may be acquired more efficiently by using the machine than by more conventional methods. For example, could the student do as well by simply reading the text or by use of prompting cards? Other problems which have not yet been investigated in detail relate to the methods of presentation of programmed material in the machine.

The purpose of the present study was to investigate different methods of presenting material in the machine, to evaluate the effectiveness of machine teaching as compared with more traditional methods, and to program parts of the Basic Electricity course of the Department of the Navy. The material used in this research consisted of selected sections of the programmed content. All experiments were conducted at Brooklyn College, and subjects were students in the College of Liberal Arts and The School of General Studies at that institution.

Preliminary studies were conducted to obtain data on the amount of material to be used in a learning session, the effectiveness of the programming, subjects' knowledge of the principles of electricity, methods of testing, etc. In these experiments, the sections on electron theory and static electricity were programmed. It was found that subjects were familiar with this material; consequently it was decided to select other parts of the electricity course for study. In the subsequent experiments, the chapters on Ohm's Law and circuits were used.

The first problem to be investigated related to the manner of presenting the material in the machine. Claims have been made that for effective learning, the programmed material must be presented in a logical, progressive sequence, and also that the best type of item is the completion type. The aim of the first experiment was to study learning efficiency for material presented in a logical order (referred to in this report as "sequential") as compared with the same material presented as a random sequence of items (to be referred to as "random"). In addition, the material was programmed into true-false, multiple-choice, and completion items to see whether the type of item would influence the course of learning. The following table shows the comparisons made:

Table 1

Design of Experiment I

		Type of Item		
		Multiple Choice	True-False	Completion
Order of Presentation	Sequential	Group 1	Group 3	Group 5
	Random	Group 2	Group 4	Group 6

Six groups of subjects (10 in each group) were used, with each group learning a particular type of item presented in one of the sequences. In all experiments, one learning session from two to three hours was used.

In order to provide subjects with the knowledge necessary for the comprehension of the material to be learned in the machine, a brief summary was provided of some basic principles of electricity, including electron theory, components of a circuit, the concepts of resistance, electromotive force, and current (this will be referred to as "pre-learning material"). The subject was first asked to study the pre-learning material. Immediately thereafter, an examination was administered which was designed to test what he had learned of this material and in addition included questions on the subject matter to be learned on the machine. (This test will be referred to as the "pre-treatment examination".) The subject then proceeded to the machine learning. Sixty items (two discs) had to be answered correctly. After he had completed this material, the subject was given a second examination ("post-treatment examination") designed to be a parallel of the first one.

Two measures of learning were used: first, the number of responses required by a subject to complete all sixty items correctly ("learning efficiency") and second, the difference between the scores on pre- and post-treatment exams ("performance gain"). Learning efficiency is defined as the number of responses required to answer all questions correctly. Since the minimum number of responses possible is 60, a score of 74 indicates that the subject made 14 incorrect responses.

The results for the first measure are shown in the following table:

Table 2

Mean Number of Responses to Criterion

		Type of Item		
		Multiple Choice	True-False	Completion
Order of Presentation	Sequential	68.3	74.2	70.2
	Random	75.3	76.6	68.6

A statistical analysis of these results shows that there is no significant difference between the random and sequential presentation of items. This is a surprising result in view of the usual recommendation that material be presented in a logical, progressive sequence. It is possible that many more than sixty items must be used in order to reveal any difference between the two orders. Perhaps, genuine randomness cannot be achieved with only sixty items. At first, it had been planned to use 120 items (four discs) but preliminary tests revealed that this amount would require an excessively long learning session and make it difficult to obtain subjects. On the basis of the above results, it can be concluded that with short learning periods, the order of presentation makes little difference. Further research is required to determine whether there would be a difference when more material is used.

Comparison of the results for the three types of items indicates that the completion items provide the most efficient learning. The mean number of responses for completion items, regardless of manner of presentation, was 69.4 which is **considerably** superior to the true-false mean of 75.4 and better than the multiple-choice mean of 71.8 but not significantly so. The least efficient learning is for the true-false item.

The following table gives the results for the second measure used - performance gain.

Table 3

Total Mean Performance Gain

		Type of Item		
		Multiple Choice	True-False	Completion
Order of Presentation	Sequential	7.4	6.2	4.7
	Random	7.0	6.2	4.7

Statistical analysis shows no significant difference between random and sequential presentations. Neither is there any significant difference between the various kinds of items. Although completion items are superior as measured by the number of responses to criterion in the learning session, they show no superiority when the measure of performance gain is applied. It might be said, therefore, that however the material is learned (i.e., by means of multiple-choice, true-false, or completion items), subjects in all groups are able to apply their knowledge in the examination. Thus, the view that manner of presentation and type of item are crucial for machine teaching is not entirely supported by the results of Experiment I.

The next problem to be investigated concerned the value of the teaching machine as compared with other educational methods. What are the unique features of the machine that make it a valuable teaching device? Firstly, it is self-instructional (once the material is programmed), secondly, the student is not passive but is forced to produce an answer, and thirdly, he is immediately informed as to the correctness of his answer. The question raised was whether these features can be duplicated in a simpler, less expensive way which is also self-instructional.

In order to investigate this question, the sixty completion items used in Experiment I were typed on index cards (referred to as "prompting cards"), one item per card. The correct answer was typed on the back of the card. The subject followed the same procedures as did the subjects who had operated the machine in Experiment I. The subject read the item, wrote down his answer, and checked it against the answer on the back of the card. He returned to the incorrect items after he had run through all the cards. Random and sequential presentations were given. The two measures used in Experiment I - number of responses to criterion and performance gain between Examinations A and B obtained. In the final experiment, 20 subjects took part.

The results for the use of prompting cards as compared to completion items are given in Tables 4 and 5:

Table 4

Mean Number of Responses for Completion Items

		Teaching Machine	Prompting Cards
Order of Presentation	Sequential	70.2	67.0
	Random	68.6	65.7

Table 5

Total Mean Performance Gain for Completion Items

		Teaching Machine	Prompting Cards
Order of Presentation	Sequential	4.7	7.1
	Random	4.7	6.1

A statistical comparison of the above means, and the means for the respective treatments yielded no significant differences between the prompting card and the teaching machine presentations as to number of responses or performance gain. This experiment, therefore, shows that the teaching machine does not contain any unique instructional features that cannot be duplicated by simpler techniques.

The next step was to compare the effectiveness of learning by machine with more traditional teaching techniques. Two additional groups of subjects were taught the same material as used in Experiment I and also were tested by the same pre- and post-examinations. The difference lay in the presentation of the material. One group learned the material by reading a prepared text and the second group by listening to a lecturer. There were 20 subjects in the text group and 40 in the lecture group. These groups were compared with the entire group of machine subjects. The duration of the lecture and text sessions was arranged so as not to exceed the time taken for machine learning; for the majority of text subjects the learning time was less than for machine subjects. The total mean performance gain for machine, text, and lecture groups is given in the following table:

Table 6

Total Mean Performance Gain

	Teaching Machine	Text	Lecture
Mean	6.1	10.6	7.9

Statistical analysis showed that text learning was significantly superior to lecture and machine learning.

In addition, the lecture group was significantly superior to the machine group. Learning by the traditional methods thus seems superior and these results, if substantiated by further research, should perhaps serve to counteract the somewhat excessively enthusiastic claims which have been made for mechanical self-instructional devices. The superiority of the lecture and text presentations might depend in part on the following:

In programming for the teaching machine, the programmer is forced to break the body of information down into the smallest steps or items of information. Then in organizing the lecture and text to cover this information, the programmer is able to structure and relate the items in an unambiguous and efficient manner.

Additional analyses were made of total performance gain scores for machine, text and lecture presentations. The pre- and post-treatment examinations consisted of items designed to test for either rote or transfer learning. Rote learning items tested the subject's memory for what he had learned. Transfer items required the subject to apply information he had learned to new problem situations, for example, a problem related to an unfamiliar circuit. Subjects' total scores could thus be analyzed into two component sub-scores for comparison. Statistical analysis indicates that there was no significant difference between any of the machine presentations in their ability to teach either rote or transfer material. However, comparison of text, lecture and machine rote and transfer to the ability to teach rote material. In other words, a brief teaching session gives rise to more rote than transfer learning, with text and lecture treatments teaching rote material better than the teaching machine under such conditions.

Another aim of the research was to determine subjects' attitudes toward the teaching machine and its adoption for classroom use. Attitude questionnaires were issued to subjects who were members of machine treatment groups immediately after the experimental treatment. Approximately 56 per cent of all machine treated Ss were generally favorable in their attitude to the teaching machine. The majority of subjects were opposed to the adoption of teaching machines for classroom use and felt that the machines were adequate for teaching mainly material to be memorized, not transfer material. The three criticisms that occurred most frequently were the lack of teacher-student relationship; the lack of opportunity to ask questions and receive additional explanation, and the tendency to respond to different questions on the basis of a remembered rather than an understood answer.

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Skinner, B. F. Teaching Machines. _Science_, 1958, 128, 969-977

APPENDIX A

Plan of Research

The experimentation to be reported sought to determine the following:

1. Is there any difference in the efficacy of teaching machine programming using completion items, multiple-choice items and true-false items?

2. What differences are there between items presented in a logical sequence and items presented randomly in each of the above types of programming?

3. Can the teaching machine be duplicated in a simpler, less expensive way which is also self-instructional?

4. How does the teaching machine compare to more traditional means of teaching such as the lecture or textbook methods?

5. What are the attitudes of students to teaching machines?

To obtain evidence relative to the above queries, a body of information taken from the Basic Electricity course of the Department of the Navy was programmed for the teaching machine using in one case completion items, in another multiple-choice items, and in a third, true-false items. The same completion items as used in the teaching machine were also printed on cards, with the answers to the items on the back of each card, and placed on a ring clip. Items for all of the above conditions were presented to different groups in a logical sequence and in a random sequence. The same body of information was presented by a lecturer and by the use of text material.

Table 7 on the following page summarizes the different teaching methods compared using the same body of information.

Selection of Subjects

Preliminary studies indicated that it was difficult to select only subjects who had little or no knowledge of electricity. However, it was considered advisable to reject the too sophisticated since, in their case, there would be little room for improvement. This was done on the basis of the subject's pre-treatment examination score. Subjects were rejected as too sophisticated if they scored 30 or above on the pre-treatment examination. Since the highest score possible on the pre-examination was 39, there would be little room for improvement for such a subject.

All subjects used were selected from the School of Liberal Arts and the School of General Studies of Brooklyn College. Subjects in each experimental group were asked to fill out a questionnaire (Appendix K) which asked Ss to indicate past or current courses taken relative to electricity. In addition, Ss were asked to check off those of a list of electrical terms and symbols with which they were familiar. The number of electrical terms and symbols the subject checked was found to be a fairly reliable index of the subject's electrical knowledge as evaluated by the examination administered prior to the experimental treatment. A correlation of r = .62 was found to exist between the number of electrical terms and symbols checked, of the list of terms and symbols on the

Table 7

The Teaching Methods Compared

Teaching Machine						Prompting Cards		Text	Lecture
Completion Items		Multiple-Choice Items		True-False Items		Completion Items			
Sequential	Random	Sequential	Random	Sequential	Random	Sequential	Random		
Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9	Group 10

questionnaire and scores on the pre-treatment examination. (See Appendix N.) Subjects were therefore matched and assigned, within each of the experimental treatments (i.e., multiple-choice, true-false, and completion items presented by the machine and by prompting cards), according to their rating on the electrical term and symbol index, to either random or sequential presentations.

It was not possible due to the availability of subjects to equate treatment groups (i.e., groups getting a particular type of item) in the same manner. A factorial analysis of variance of the pre-treatment examination scores yielded a significant F ratio at the .01 level between true-false, multiple-choice and completion item groups (See Appendix N). By comparison, the sum of squares for random and sequential presentations was extremely low, undoubtedly reflecting the matching of subjects within treatment groups and assignment to either random or sequential orders. It was decided to control for initial differences between treatment groups statistically. An analysis of variance design using differences between scores on the pre- and post-treatment parallel exams was adopted to compare all teaching methods. The difference between the pre- and post-treatment exams is referred to as "performance gain" (see below).

General Experimental Procedure and Materials

Subjects reported for one session approximately two to three hours in length. The general procedure used with each subject in all experiments reported here was as follows:

1. Each subject received a questionnaire to complete (Appendix K).
2. If the subjects were a part of an experimental group to be taught by the teaching machine they next received printed directions as to the operation of the machine (Appendix K).
3. Subjects then received "Pre-Learning" material (Appendix K), which was intended to familiarize Ss with basic information necessary for the comprehension of material used in the learning session and to bring all subjects up to or above a base line of information, thereby assuring that a subject's learning of later material was not influenced by a lack of knowledge of more basic information. Ss were directed to study the pre-learning material thoroughly.
4. Upon completion of the pre-learning material an examination was administered which was a parallel examination to the one to be administered after the experimental treatment (see Appendix I). The pre-treatment examination was administered in order to:
    a. Test the subject's absorption of the pre-learning material.
    b. Determine the level of the subject's knowledge of electrical information programmed in the experimental treatment.
    c. Prompt recall of electrical information previously studied by S.
    d. Provide a means of measuring and comparing the experimental treatments.

5. After completion of the pre-examination, Ss were placed in the learning situation.

6. Upon completion of the learning session, Ss were asked if they wished to take a brief intermission. Preliminary experiments indicated that learning sessions of two to three hours might be somewhat tedious. Very few Ss, however, wanted to rest.

7. A protocol relative to the Ss attitude to the teaching machine was administered immediately after the presentation of material in the machine (Appendix K). Subjects in groups which did not use the teaching machine were not asked to fill out a protocol.

8. Subjects received the second examination (Appendix K).

Measures of Learning

Initially, both the number of responses and the amount of time taken by the subject to complete the learning material was recorded. However, mechanical breakdowns of the teaching machine and miscellaneous interruptions relative to machine operation made it such that time was not a reliable index of teaching efficiency. Length of time to complete a "no error" run was therefore discarded in favor of one measure, the number of responses required to complete a "no error" run.

1. Learning efficiency was defined as the number of responses required to answer all items presented in the machine or answer prompting cards correctly. In the tables of results this measure is referred to as the number of responses to criterion. The lower the number of responses, the greater the learning efficiency.

2. Performance gain was defined as the difference between the subject's scores on the pre- and post-examinations. Each examination consisted of three types of questions:

    a. Pre-learning questions - to test for knowledge of the pre-learning material.

    b. Rote questions - to test the subject's memory for what he had learned in the learning session (machine, card, text or lecture).

    c. Transfer questions - to test the subject's ability to apply the information learned to a new problem situation (see Appendix H for further details).

Statistical Comparisons

1. The various machine and prompting card groups were compared as to learning efficiency with regard to order of presentation and type of item.

2. The performance gains of the machine groups were compared with respect to order of presentation and type of item.

3. The machine completion subjects were compared to the prompting card completion groups as to order of presentation and type of item.

4. The attitude scores of the various teaching machine groups were compared.

5. The total teaching machine group (N = 60) was compared with the lecture (N = 40) and text (N = 20) groups with respect to performance gains.

6. For the groups using the teaching machine a correlation was computed between subjects' protocol scores and performance gain.

7. A correlation coefficient was computed between learning efficiency and performance gain.

APPENDIX B

Experiment I

PURPOSE

The aim of Experiment I was to compare learning performance with the teaching machine using in one case completion items, in another, multiple-choice items, and in a third, true-false items. In a supplement to Experiment I, completion items on prompting cards were compared to machine presentation.

MATERIALS AND PROCEDURE

Subjects were presented with a body of information to learn covering the following electrical topics: Ohm's Law, series connections, operations of a battery and voltage drop.

The information was programmed for the teaching machine using a total of 60 items (two machine discs). There were therefore 60 completion items, 60 multiple choice and 60 true-false items. Each set of questions in each experimental condition was arranged in one case in a logical sequence and in the other case in a random order (see Appendix H for a complete discussion of programming).

Discs were presented in the Skinner Teaching Machine. Some items required schematic diagrams; these were drawn on 5" x 7" white cards and the item number placed on the cards (see Appendix H). The cards were then clipped on to a ring in numerical order and placed on top of the teaching machine for appropriate use. It was not possible to draw the diagrams on the disc because of a lack of space.

Subjects were given material in the following order:

1. Questionnaire (Appendix K).
2. Pre-learning material (Appendix K).
3. Pre-treatment examination (Appendix K).
4. Instructions on the operation of the machine.
5. Machine learning session.
6. An attitude questionnaire relative to the machine (Appendix K).
7. Post-treatment examination (Appendix K).

An introduction to the experiment (Appendix M) was discarded as being unnecessary and burdensome reading for the subject. The introduction included information which could be concisely and clearly presented by the experimenter verbally at the start of the experimental period or at the time the subject signed up for the experiment.

SUBJECTS

A total of 67 Ss (male and female) were used. For purposes of statistical comparison, group N's were equated (N = 10) by random selection after first rejecting subjects in accordance with the procedure outlined above.

EXPERIMENT Ia

PURPOSE

The aim of this supplementary experiment was to compare the teaching machine with prompting cards, a simpler self-instructional technique.

MATERIALS AND PROCEDURE

The same 60 completion items as used in the teaching machine were preseented to an additional group of subjects on prompting cards, one item to a card. The questions were printed on one side and the answer on the other. Subjects were given the following instructions designed to correspond with the manner in which the machine mechanically presented items to be learned.

> You are to learn the material presented on these cards. For experimental purposes you must follow the experimental procedure outlined to you very carefully. Number your answer sheet from 1 to 60. There are 60 cards each with one question on it. Try to answer question number one. Turn the card over and you will see the correct answer. If your answer is correct, merely proceed to question number two. If your answer does not agree with the answer on the card, draw a line through your answer. Do not write the correct answer on your answer sheet. Then proceed to question two. Continue in this fashion through question number 60. You will then return to the questions you did not get correct the first run through the cards. Re-answer the questions you got wrong in numerical order and follow the exact same procedure as before. If you get some items wrong a second time then return to them after you have completed your second run through the incorrect items you got wrong the first time. You must, of course, not look at the answer before you attempt to answer the question. For experimental reasons it is very important that you follow the outlined procedure carefully.

No difficulty was encountered in eliciting the cooperation of all subjects in the prompting card group. Ss in this group were continually made aware of the experimenters' presence during the experimental period, to control for any possible infraction of the outlined procedure.

The same diagrams as used with the teaching machine were employed here. The prompting card subjects received the same material in the same order as the teaching machine groups as listed above. One group received the items in a sequential order and another group in a random order.

SUBJECTS

A total of 37 subjects (male and female) were used in Experiment Ia. For purposes of statistical comparison group N's were equated (N = 10) by random selection after first rejecting subjects in accordance with the procedure described above.

RESULTS

1. Learning Efficiency.

Table 8 indicates the mean number of responses required by Ss to complete all 60 items correctly. This represents the measure for learning efficiency. Results for all Ss are given in Appendix F.

Table 8

Mean Number of Responses to Criterion

		Machine			Prompting Cards
		Type of Item			
		Completion	Multiple Choice	True-False	Completion
Order of Presentation	Sequential	70.2	68.3	74.2	67.8
	Random	68.6	75.3	76.6	65.7

A factorial analysis of variance of the above results yielded the following:

Table 9

Comparison of Machine and Prompting Card Groups as to Mean Number of Responses to Criterion

Source of Variation	df	MS	F
Between Treatments	3	292.85	6.16**
Between Random and Sequential*	1	53.21	1.12
Treatment x (R and S)	3	80.61	1.69
Within	72	47.50	
Total	79		

** .01 level of confidence.

* Indicates random and sequential orders of presentation, respectively.

The between treatments F ratio reaches significance at the .01 level. Random and sequential and the interaction effects fail to reach significance. The treatment response means are listed in the following Table 10 without respect to random or sequential presentations.

Table 10

Mean Number of Responses Within

Treatments to Criterion

	Machine			Prompting Cards
	Completion	Multiple Choice	True-False	Completion
Mean	59.4	71.8	75.4	55.3

A t test comparison of all means given in Table 10 yields the following results shown in Table 11:

Table 11

Comparison of Mean Number of Responses

to Criterion

	Machine		Prompting Cards
	Multiple Choice	True-False	Completion
Machine Completion	0.78	1.95	1.01
Multiple Choice		1.17	1.79
True-False			2.95**

** .01 level of confidence

The true-false items give rise to a significantly larger mean number of responses than the completion items using prompting cards. The true-false items barely miss being significantly different from the machine completion at the five per cent level. Among all the remaining comparisons there are no significant differences.

It is concluded that the true-false items lead to the minimum learning efficiency. It might be suggested that the subjects in the true-false group were the most naive and thereby their response scores are considerably higher than the other groups. However, if the pre-treatment examination scores are accepted as a measure of naivete relative to the subject matter then a t test comparison of pre-treatment score means indicates that the multiple-choice group (mean = 11.8) can be considered as naive as the true-false group (mean = 13.3) and both these groups as significantly more naive than the completion group (means: machine = 18.3; cards = 16.8). While the multiple-choice group average learning efficiency (71.8) is not significantly lower than the completion group's (69.4; 66.3), the true-false group's learning efficiency (75.4) is lower. Thus it can be inferred that it is the type of item that leads to lower learning efficiency.

A zero correlation (r = .002) was found to exist between the number of responses (learning efficiency) and the performance gain as measured by the improvement in score between pre-treatment and post-treatment examinations. This suggests that there is no relationship between speed of learning and the amount learned in this experimental situation (see Appendix N).

2. Performance Gain

Results for all Ss on the pre- and post-treatment examinations are listed in Appendix E. Table 12 gives the mean rote and transfer performance gains. The total mean performance gain is equal to their sum.

Table 12

Rote and Transfer Performance

Gain*

	Multiple-Choice		Completion		True-False	
	Random	Sequential	Random	Sequential	Random	Sequential
Rote	4.2	4.4	3.5	2.1	4.4	4.2
Transfer	2.8	3.0	1.2	2.6	1.8	2.0
Total	7.0	7.4	4.7	4.7	6.2	6.2

*Absolute rote, transfer and total performance gains are given in Table 11. For purposes of statistical comparison five points were added to all rote and transfer performance gains in order to eliminate negative scores (i.e., score reversals).

A factorial analysis of variance with repeated measurements yielded the following results:

Table 13

An Analysis of Variance With Repeated Measurements of Machine Treatment Performance Gain

Source of Variation	df	MS	F
Between Treatments	2	16.03	1.76
Between R and S	1	.03	-
Treatments x (R and S)	2	.23	-
Between Ss in same group	54	9.08(e)	
Between	59		
Between Rote and Transfer	1	76.80	7.95**
Treatment x (Rote and Transfer)	2	6.90	-
R and S x (Rote and Transfer)	1	9.64	-
Treatment x (R and S) x (R and T)	2	5.43	-
Pooled Ss x Rote and Transfer	54	9.66(e)	
Within	60	10.55	
Total	119		

Note - The (e) indicates the error term used to obtain the F value reported above it.

****.01 level of confidence**

The order of presentation and type of item within the limits of a sixty item program did not give rise to any difference in the amount learned as measured by performance gain. The analysis yielded only one significant difference. Except in the case of completion items sequentially presented, the teaching machine, regardless of the order of presentation or type of item, taught rote material better than transfer material. Inspection of the means in Table 12 showed that the completion items sequentially presented gave rise to a slightly higher mean transfer score than mean rote score. However, all the other rote gains were greater than the transfer performance gains. Therefore, within the limits of one learning session, the teaching machine resulted in more rote than transfer learning.

The performance gains for the completion items for prompting cards and machine subjects are given in Table 14:

Table 14

Rote and Transfer Performance Gains (Completion items)

	Machine		Prompting Cards	
	Random	Sequential	Random	Sequential
Rote	3.5	2.1	4.3	4.8
Transfer	1.2	2.6	1.8	2.3
	—	—	—	—
Total	4.7	4.7	6.1	7.1

A factorial analysis of variance with repeated measurements of completion machine and prompting card scores yielded the following results:

Table 15

The Analysis of Variance with Repeated Measurements

of Machine and Prompting Card Completion

Performance Gains

Source of Variation	df	MS	F
Between Machine and Prompting Cards	1	26.10	1.85
Between Random and Sequential	1	1.25	-
Treatment x (R and S)	1	20.55	1.46
Between Ss in the same group	36	14.07(e)	
Between Rote and Transfer	1	57.80	5.19*
Treatment x (Rote and Transfer	1	4.75	-
R and S x (Rote and Transfer)	1	9.80	-
Treatment x (R and S) x (Rote and Transfer)	1	9.80	-
Pooled Ss x (Rote and Transfer)	36	11.13(e)	
Total	79		

Note - The (e) indicates the error term used to obtain the F value reported above it.

* .05 level of confidence

The analysis showed no statistical difference between the prompting card and the teaching machine presentations. The prompting cards, however, resulted in better rote than transfer learning.

APPENDIX C

Experiment II

PURPOSE

The purpose of this experiment was to compare learning performance on the basis of three different teaching methods: teaching machine, classroom lecture and textual presentation.

MATERIALS AND PROCEDURE

A modification in the experimental design was employed with the lecture group subjects to enable the experimenters to determine whether the pre- and post-treatment examinations were parallel. For half of the group the pre-treatment examination was used as the post-examination and vice-versa for the other half (see Appendix I).

Subjects were presented with the same body of information to learn as subjects in Experiment I and Ia. Subjects received material in the following order:

1. Questionnaire (Appendix K).
2. The pre-learning material (Appendix K).
3. Pre-treatment examination (Appendix K).
4. Text or lecture learning session.
5. Post-treatment examination.

LECTURE PROCEDURE

Subjects were told to treat the experimental learning session as a normal classroom situation. Subjects were told that they could employ whatever study habits they wished. They were given paper on which to take notes and informed that they could ask questions. The lecturer organized the material to be taught so that it paralleled the teaching machine program. Blackboard diagrams were employed freely. Questions were directed to the class to encourage participation.

In answering questions raised by members of the group, the lecturer was careful to avoid undue amplification of any particular point. At the conclusion of the lecture, the group was invited to raise any questions they wished. These were answered, Ss' notes were then collected and the blackboards erased. After a five-minute break the post-treatment examination was administered.

TEXT PROCEDURE

Before distributing the texts, Ss were instructed to proceed at any pace they wished. They were told they might mark up the sheets in any manner - underline, write questions, work out examples, diagrams, etc. As each S finished the text it was turned in and after a five minute break, the post-treatment examination was administered.

SUBJECTS

A total of 60 subjects (male and female) were used. Forty subjects received the lecture and twenty subjects the text material. The groups were compared to the 60 teaching machine subjects. Subjects were rejected in accordance with the procedure outlined above.

RESULTS

Score results for all subjects on the pre- and post-treatment examinations are listed in Appendix E. Table 16 lists the mean rote, transfer and total performance gains for the three treatments.

Table 16

Rote and Transfer Performance Gain*

	Teaching Machine	Text	Lecture
Rote	3.8	6.9	6.1
Transfer	2.3	3.7	1.8
Total	6.1	10.6	7.9

* Absolute rote, transfer and total performance mean gains are given in this table. For purposes of statistical comparison, 5 points were added to all rote and transfer performance gains in order to eliminate negative scores (i.e., score reversals).

A factorial analysis of variance with repeated measurements yielded the following results:

Table 17

An Analysis of Variance with Repeated Measurements of Lecture, Text and Teaching Machine Performance Gains

Sources of Variation	df	MS	F
Between Treatments	2	81.70	8.24**
Between Ss in same group	117	9.91(e)	
Between Rote and Transfer	1	464.82	50.20**
Treatment x (R and T)	2	47.12	5.09**
Pooled Ss x (R and T)	117	9.26(e)	
Total	239		

Note - The (e) indicates the error term used to obtain the F value reported above it.

** .01 level of confidence

A series of *t* tests were made to determine the specific significant difference existing between groups compared in the above analysis of variance. The results are as follows:

Table 18

Comparison of Means of Lecture, Text, and Machine Performance Gains

			Text		Lecture	
	Text	Lecture	Rote	Transfer	Rote	Transfer
Machine	5.62**	2.81**				
Text		3.14**				
Machine Rote			2.77**		2.62**	
Machine Transfer				1.25		0.57
Text Rote					0.68	
Text Transfer						1.61

** .01 level of confidence

The *t* tests indicate that rote items contribute significantly to differences between machine and the lecture and text presentations with lecture and text treatments giving rise to superior rote performance gains. There appears to be no significant difference between the ability of text or lecturer to teach rote material. The teaching machine compared to text and lecture treatments is not significantly different as to transfer performance gains; however, text gives rise to a superior transfer performance gain which is not quite significant at the .05 level to lecture presentation. Regardless of the form of presentation rote material is learned better than transfer material as evidenced by the significant difference in the analysis of variance. The text presentation, with superiority to the lecture in both transfer and rote items and to machine presentation in rote items can be said to be the superior form of presentation giving rise to the maximum learning within the limits of the experimental situation. In other words, one learning session gives rise to more rote learning when tested by immediate recall and text presentation teaches material to a superior extent than other methods under such conditions.

APPENDIX D

Discussion of Experiments

I AND II

I Sequential and Random Programming

There are two bases for comparing sequential and random programming. One is the number of responses. The other is the performance gain. Learning time was not used as a basis for comparison because of the recurrent interruptions and delays encountered due to the frequent difficulties and breakdowns in the operation of the teaching machines. The results of Experiment I indicate that there is no evidence that sequential and random programming give rise to different results either with regard to learning efficiency or performance gain.

A Number of Responses

Traditionally material is taught in a logical incremental pattern with new concepts drawn from or applied to preceding ones. It is theoretically possible for a student to complete without error a machine program of logically ordered material. Under actual experimental condtions some errors will occur. It is expected, that a random or illogical order of presentation will result in a greater number of errors. The experimental results, however, show that there was no statistical significance between the number of errors in a sequential and in a random presentation for any of the four treatments, nor was there any discernable tendency towards a difference.

There are several possible explanations for this result. The traditional hypothesis of the theory of teaching may not be true for a program of limited size, such as the 60 items used here. It is unlikely, however, that the traditional approach is inapplicable here merely because of the size of the program. It may be that although the items were randomized statistically, they were not completely randomized logically. For example, Ohm's law was mentioned in 27 of the 60 items. Some quasi-logical grouping of these items must have occurred in certain sub-sections of the program. In the traditional teaching procedure material is often reviewed. Randomizing, therefore, might sometimes be providing an opportunity for review rather than disrupting the sequence of logical programming.

There was no correlation between the manner of presentation and the subjects opinion of whether the presentation was logical or not. This lends support to the second hypothesis mentioned above.

B Performance Gain

The difference in total performance gain between sequential and random presentation was not statistically significant.

In each of the four treatments, however, there was a higher mean performance gain (not statistically significant) for sequential than for random in the case of transfer learning. This uniform gain did not appear in rote or in total learning. Perhaps a sequential presentation is more effective in teaching insightful material. Since insightful learning, by definition, depends on the development and application of concepts, we might conclude that the teaching of concepts benefits from a logical order of presentation. Rote learning, on the other hand, does not.

II Comparison of Multiple Choice, True-False and Completion Treatments

A. Number of Responses:

There were statistically significant differences among the number of responses to criterion (learning efficiency) in the above machine and prompting card treatments. True-false items in the teaching machine required, on the average, a larger number of responses to complete a "no-error" run, than completion (machine) or completion (cards) items. True-false required more responses than multiple choice, but not significantly; and multiple choice items, in turn, required more responses than completion (machine) and completion (cards) but **significantly** appears only in comparison with completion (cards). The pre-treatment examination indicates that the true-false was not the most naive of the four groups. Thus the above differences cannot be attributed to such a bias. It is therefore suggested that true-false programming was the least efficient of the four treatments, with multiple choice items appearing to fall somewhere between completion items and true-false items.

There are several reasons for this, some of them inherent in the methodology of true-false presentation. The subject is asked to select one of two choices; this may result in his guessing rather than trying to work out the answer. Furthermore, an item to which the answer is "false" gives the subject no positive information, whereas the answers in the other treatments do. He thus has no way of determining the correct answer. Another reason is that a subject answering a true-false item has a 50% chance of being correct, regardless of his knowledge relative to the item. If he answers a question correctly on the machine he goes on to the next question and never sees the former again. He may thus be presented with knowledge in this question which is required to answer some subsequent questions; S may answer the latter incorrectly because he lacks this knowledge.

Completion items, regardless of machine or prompting card presentations, gave rise to maximum learning efficiency (i.e. the same amount of information is learned with less average errors to criterion.) With completion items, there was less opportunity for guessing and greater means for a subject to be presented with correct information in the answer to the item.

B. Performance Gain

Multiple choice, true-false and completion programming did not give rise to any significant difference in mean performance gain. It appears, therefore, that the amount learned, as measured by difference between pre- and post-examination scores was the same for the machine and prompting card groups in Experiment I. The first point of interest is that prompting cards performed as well as teaching machine presentation.

An important consideration is the limits of the teaching period used in the experiment. One might well expect to obtain significantly different results if a longer learning session had been used. One would expect true-false items, for example, with their minimum learning efficiency, to give rise in a longer learning session to significantly less performance gain. In addition, it must be remembered that only an immediate recall test of learning has been elicited. A delayed retention test might have yielded different results from those obtained here.

Under the present experimental conditions, no correlation was found to exist between the number of responses (learning efficiency) and performance gain. The possible explanations for this result are:

1. The brevity of the learning session.

2. There is no necessary relationship between number of responses and amount learned.

III Comparison of Machine, Lecture and Text Presentations

The results of Experiment II yielded signifcant results, with text presentations superior to the machine and lecture. Lecture presentation was significantly better than machine. Specifically, rote material appears to contribute significantly to the differences found. The results show that the lecture does not do as well as the machine in the teaching of transfer material although the difference is not significant. Neither does text teach transfer material significantly better than the machines, although the difference favored the text method. The superiority of the text and lecture to the machine can be attributed to the amount of rote material learned. The explanation offered is that within the limited learning period of one session, rote material is learned better regardless of the form of presentation as evidenced by the significant differences obtained. If any differences are attributable to the teaching treatment, then a comparison of treatments should give rise to significant results. Insight into a topic, however, may require time or contemplation that will not reflect in an immediate recall test of learning. Therefore, since rote material is the easiest to learn, text as a superior teaching instrument, will teach more efficiently and completely material that S can grasp within the confines of a 50-minute learning session.

Another possible explanation is in the selection of certain items in the examinations as reflecting rote learning and others as reflecting transfer learning. The choice was subject to selection on the part of the experimenters after careful scrutiny of the content of each examination item. The criterion followed in the determination of rote and transfer items was whether the question required S merely to apply information in the same manner as it was originally learned, or to apply the learned material in a new context.

The text is also significantly superior to lecture presentation. It is felt that the superiority of text material might be attributable to any one or all of the following reasons:

1. Text material affords the greatest opportunity for review in comparison to machine, prompting card and lecture presentation. Ss were allowed to study and return to any part of the text material they wished. Therefore Ss could overlearn any section and reinforce by repetitive reading and scanning information in the text. Returning to items one previously gets correct("learned") in the teaching machine or with the prompting cards is not possible. Therefore S cannot reread items previously termed correct (but unfortunately not learned.) The lecture is also limited in its review ability because Ss note-taking cannot be controlled for. In addition, Ss notes were taken from him at the completion of the experiment session, to enable the experimenters to compare a lecture presentation uncontaminated by any "text" factors with the other treatments. However, it would be interesting to compare a lecture presentation with note-taking encouraged

(or required) and subsequent reading of notes with the machine and text treatments.

2. Another possible advantage of text is that it affords maximum opportunity to present material in an organized and related fashion. Space can be devoted to developing a relationship which might be very difficult to present in an incremental manner as demanded by the teaching machine. This comment leads us into the third possible reason for the obtained superiority of text material.

3. The text might give significantly superior results because the programming of the body of information for the machine perhaps was not sufficiently well developed. A new programming was designed and is given in Appendix H of this report. However, time limitations prevented the use of the new programming. Again, it must be stated that the new programming, although apparently superior to the one used, might not give significantly different results.

IV The Attitude of Subjects to Teaching Machines

The question arises whether students required to use teaching machines will be, in the main, positive or negative in their attitude. A student's negative attitude may seriously detract from the teaching machine's ability to teach. A highly negative student is unlikely to pay much attention to information presented in a manner he either scorns or finds distasteful.

The attitudes of the subjects do not appear to vary in any determinable fashion with performance gain scores, and cannot be said to be influencing them in any determinable manner. Subjects appear to learn, within the confines of 60 items or 50 minutes, regardless of their attitudes. Again, the time and length limits of the program might be the cause for this lack of correlation. If these results are confirmed by later studies, then the negative attitude of subjects to teaching machines may not be a central factor to be considered in the teaching efficacy of the machines. Students, may learn from the teaching machines in spite of their attitudes.

General Conclusions

1. True-false items give rise to the least learning efficiency, lowest average total performance gain (not significant), and the lowest transfer performance gain (not significant).

2. Completion items, multiple choice items, and true-false items do not lead to any differences in mean performance gain.

3. The prompting cards are as efficient as teaching machines in their ability to teach.

4. Text and lecture are superior to the teaching machine as a teaching method as measured by total mean performance gain scores.

5. Rote material is learned better than transfer material under these experimental conditions, and can be said to be the factor that significantly interacts with the experimental treatments.

6. Attitudes of subjects toward the teaching machine are generally favorable.

7. Attitudes of subjects toward the machine are not correlated with performance gain.

APPENDIX E

Table 19

Pre- and Post-Treatment Exam Scores

Machine - Completion (Sequential)

	Exam A as Pre-Treatment Exam				Exam B as Post-Treatment Exam			
Subject	Pre Learning Items	Rote Test Items	Transfer Test Items	Total	Pre-Learning Items	Rote Test Items	Transfer Test Items	Total
1	5	5	3	13	5	11	7	23
2	5	12	4	21	4	9	8	21
*3	3	3	3	9	4	3	3	10
4	5	10	5	20	4	13	4	21
5	5	9	3	17	5	13	6	24
6	5	7	3	15	5	5	2	12
7	4	6	0	10	5	7	2	14
8	4	4	1	9	4	14	5	23
9	5	12	9	26	5	12	10	27
10	5	12	5	22	5	15	9	29
11	4	10	5	19	5	9	11	25
*12	5	11	7	23	5	13	13	31
Completion - Random								
1	5	12	3	20	5	12	5	22
2	5	10	5	20	4	16	7	27
3	5	10	10	25	5	12	8	25
4	4	13	10	27	5	13	13	31
5	5	6	4	15	5	2	0	7
6	5	3	1	9	5	10	5	20
7	5	1	5	11	5	12	11	28
8	4	10	3	17	5	12	3	20
9	5	8	11	24	5	17	9	31
10	5	12	10	27	4	14	13	31
*11	5	2	0	7	4	9	1	14

*Asterisked scores represent rejected subjects.

APPENDIX E

Table 20

Pre- and Post-Treatment Exam Scores

Machine - Multiple Choice (Sequential)

	Exam A as Pre-Treatment Exam				Exam B as Post-Treatment			
Subject	Pre Learning Items	Rote Test Items	Transfer Test Items	Total	Pre-Learning Items	Rote Test Items	Transfer Test Items	Total
1	5	7	3	15	5	9	9	23
2	5	4	4	13	5	13	6	24
3	4	2	3	9	4	12	3	19
4	5	6	3	14	4	9	3	16
*5	4	5	3	12	5	4	3	12
6	5	2	1	8	5	9	6	20
7	5	4	1	10	4	8	6	18
8	4	7	3	14	5	13	10	28
9	4	5	0	9	5	10	2	17
10	5	8	4	17	5	7	6	18
11	5	12	5	22	5	11	6	22
Multiple Choice (Random)								
1	5	6	4	15	5	7	5	17
2	5	1	0	6	5	3	0	8
3	5	6	1	7	5	11	5	21
*4	5	7	5	17	5	10	10	25
5	5	3	1	9	5	8	3	16
6	5	3	5	13	5	10	8	23
7	5	0	3	8	5	5	4	14
8	5	1	0	6	4	10	8	22
9	4	4	4	12	5	5	5	15
*10	5	7	5	17	5	12	7	24
11	5	2	1	8	5	4	3	12
*12	5	4	0	9	5	11	2	18
13	5	7	4	16	5	12	10	27

APPENDIX E

Table 21

Pre- and Post-Treatment Exam Scores

Machine - True-False (Sequential)

	Exam A as Pre-Treatment Exam				Exam B as Post-Treatment Exam			
Subject	Pre-Learning Items	Rote Test Items	Transfer Test Items	Total	Pre-Learning Items	Rote Test Items	Transfer Test Items	Total
1	5	2	8	15	4	12	10	26
2	4	3	2	9	5	3	3	11
3	5	6	0	20	5	13	9	27
4	5	8	9	22	5	11	11	27
5	5	4	3	12	5	8	4	17
6	5	3	0	8	5	6	6	17
7	5	2	2	9	5	5	3	13
8	5	10	6	21	5	11	7	23
9	4	4	7	15	5	11	5	21
10	5	5	0	10	5	9	8	22

True-False (Random)

Subject	Pre-Learning Items	Rote Test Items	Transfer Test Items	Total	Pre-Learning Items	Rote Test Items	Transfer Test Items	Total
1	4	0	0	4	2	7	1	10
2	5	7	10	22	5	11	14	30
3	5	6	3	14	5	10	1	16
4	5	3	1	9	5	3	3	11
5	5	2	2	9	5	6	2	13
6	5	9	4	18	5	14	8	27
7	5	4	4	13	5	8	8	21
8	4	0	1	5	5	6	5	16
9	5	3	2	10	5	10	3	18
10	5	8	8	21	5	13	8	26

APPENDIX E

Table 22

Pre- and Post-Treatment Exam Scores

Prompting Cards (Sequential)

	Exam A as Pre-Treatment Exam				Exam B as Post-Treatment Exam			
Subject	Pre-Learning Items	Rote Test Items	Transfer Test Items	Total	Pre-Learning Items	Rote Test Items	Transfer Test Items	Total Total
* 1	5	8	3	16	5	5	5	15
* 2	5	13	13	31	5	17	14	36
3	5	9	5	19	5	9	11	25
4	5	10	3	18	5	17	9	31
5	5	2	3	10	5	7	3	15
* 6	5	4	5	14	5	14	7	26
7	5	2	2	9	5	13	0	18
* 8	5	4	2	11	5	12	3	20
9	5	10	5	20	5	14	3	22
10	5	9	5	19	5	12	6	23
*11	4	4	0	8	4	8	3	15
*12	5	2	2	9	5	8	2	15
13	5	4	0	9	5	11	3	19
*14	5	2	2	9	5	14	5	24
15	5	6	5	16	5	9	8	22
*16	5	11	9	25	5	13	6	24
*17	5	10	2	17	4	15	10	29
18	4	11	10	25	5	13	14	32
19	5	7	1	13	4	13	5	22
*20	5	14	7	26	5	17	12	34

APPENDIX E

Table 23

Pre- and Post-Treatment Exam Scores

Prompting Cards - (Random)

	Exam A as Pre-Treatment Exam				Exam B as Post-Treatment Exam			
Subject	Pre-Learning Items	Rote Test Items	Transfer Test Items	Total	Pre-Learning Items	Rote Test Items	Transfer Test Items	Total
1	3	10	8	21	3	11	10	24
2	5	12	10	27	5	11	12	28
*3	4	6	3	13	5	13	6	24
*4	5	4	2	11	5	12	0	17
*5	5	9	11	25	5	14	6	25
6	5	7	1	13	5	8	8	21
7	5	13	6	24	5	9	4	18
8	5	6	7	18	5	11	9	25
9	5	5	3	13	4	13	6	23
10	5	3	3	11	5	16	7	28
*11	5	3	0	8	5	13	1	19
12	5	1	3	9	5	10	3	18
*13	5	6	3	14	5	12	4	21
*14	5	11	6	22	4	16	9	29
15	4	12	9	25	5	17	9	31
*16	5	9	8	22	5	8	5	18
17	5	3	10	18	5	9	10	24

APPENDIX E

Table 24

Pre- and Post-Treatment Exam Scores

	Lecture							
	Exam B as Pre-Treatment Exam				Exam A as Post-Treatment Exam			
Subject	Pre-Learning Items	Rote Test Items	Transfer Test Items	Total	Pre-Learning Items	Rote Test Items	Transfer Test Items	Total
1	5	11	10	26	5	15	14	34
2	4	10	7	21	5	14	13	32
3	3	9	11	23	5	8	9	22
4	5	7	6	18	5	9	5	19
5	5	11	13	29	5	18	13	36
6	5	3	2	10	4	10	5	19
7	4	4	3	11	5	15	7	27
8	3	7	4	14	5	13	3	21
9	4	6	1	11	5	14	10	29
10	5	13	5	23	5	18	7	30
11	5	3	7	15	5	9	8	22
12	4	6	1	11	5	16	4	25
13	4	12	7	23	5	14	7	26
14	5	4	4	13	5	11	5	21
15	5	4	5	14	5	16	5	26
16	5	2	5	12	5	9	5	19
17	4	8	3	15	5	15	2	22
18	5	5	3	14	5	15	7	22
19	5	15	9	29	5	16	15	36
20	5	12	10	27	5	15	10	30
21	5	4	4	13	5	13	5	23

APPENDIX E

Table 25

Pre- and Post-Treatment Exam Scores

	Text							
	Exam A as Pre-Treatment Exam				Exam B as Post-Treatment Exam			
Subject	Pre-Learning Items	Rote Test Items	Transfer Test Items	Total	Pre-Learning Items	Rote Test Items	Transfer Test Items	Total
1	5	2	0	7	5	15	9	29
2	4	5	3	12	4	11	5	20
*3	5	17	12	34	5	18	13	36
4	4	8	6	18	5	17	10	32
5	5	4	1	10	5	13	7	25
6	5	10	3	18	5	15	5	25
7	5	1	0	6	5	14	6	25
8	0	4	0	4	2	5	2	9
9	5	6	7	18	5	13	9	27
10	4	11	3	18	4	9	9	22
11	4	2	4	10	5	11	3	19
*12	5	14	13	32	5	16	13	34
13	5	9	3	17	5	9	5	19
14	5	2	0	7	5	14	1	20
15	3	2	0	5	1	5	1	7
16	5	5	4	14	4	17	9	30
17	5	6	0	11	5	9	6	20
18	5	3	2	10	5	12	6	23
19	4	1	3	8	5	11	8	24
20	5	2	0	7	5	9	5	19
21	5	3	1	9	4	10	9	23
*22	5	15	13	33	5	17	11	33
*23	5	14	16	35	5	17	14	36
24	5	11	8	24	5	16	8	29

APPENDIX E

Table 26

Pre- and Post-Treatment Exam Scores

Lecture

	Exam A as Pre-Treatment Exam				Exam B as Post-Treatment			
Subjects	Pre-Learning Items	Rote Test Items	Transfer Test Items	Total	Pre-Learning Items	Rote Test Items	Transfer Test Items	Total
1	4	5	6	15	5	15	8	28
2	5	11	7	23	5	15	9	29
3	5	9	11	25	5	18	12	35
4	5	11	4	20	4	11	6	21
5	4	14	4	22	5	18	8	31
6	4	4	2	10	5	16	2	23
7	5	6	2	13	5	15	3	23
8	5	4	5	14	5	11	4	20
9	4	5	1	10	5	7	3	15
10	5	6	1	12	5	12	5	22
11	5	13	9	27	5	14	13	32
12	5	3	4	12	5	11	3	19
13	4	2	8	14	3	9	11	23
14	5	6	5	16	4	12	5	21
15	3	9	2	14	5	16	8	29
16	5	13	13	31	5	16	15	36
17	5	0	7	12	5	11	5	21
18	3	5	7	15	5	9	7	21
19	4	5	1	10	4	13	4	21

APPENDIX F

Table 27

Number of Responses by S to Complete a "No-Error" Run as a Measure of Learning Efficiency

Teaching Machine				Prompting Cards			
Completion Items		Multiple Choice Items		True-False Items		Completion Items	
Random	Sequential	Random	Sequential	Random	Sequential	Random	Sequential
67	69	74	63	84	82	68	* 70
68	62	86	69	72	84	66	* 61
62	* 98	78	67	76	72	* 69	64
66	68	* 65	* 70	85	70	* 65	62
82	70	74	76	84	84	* 64	74
74	74	67	63	74	69	69	* 66
62	78	86	72	68	73	62	69
74	87	78	64	90	68	67	* 61
67	62	60	78	66	72	65	61
64	68	* 66	69	67	68	61	65
* 72	64	86	62			* 71	* 86
	* 64	* 61				70	* 68
		64				* 78	73
						* 69	* 63
						62	63
						* 62	* 68
						67	* 61
						* 65	62
							77
							* 61

Note:- Subjects with asterisks next to their response scores were not included in the statistical comparisons.

APPENDIX G

EXPERIMENT A

PURPOSE

The aim of this experiment was to serve as guide in planning and conducting the main experiments 1 and 2. Some of the information the experimenters sought:

1. Length of time necessary to complete one disc to "no error" criterion.

2. Best procedure in instructing Ss on the operation of the teaching machine.

3. Preliminary trends to indicate how results for random and sequential programming might differ.

4. General level of sophistication of Ss that would be used in the main experiments.

5. Attitude of Ss toward the experiment.

MATERIALS AND PROCEDURE

Programming was prepared covering the topics "What Electricity Is" and "Static Electricity". A completion type of treatment was used. "What Electricity Is" was programmed in 30 items (disc a) and "Static Electricity" in 60 items (discs b and c). On these three discs the items were presented in a logical (sequential) order. Corresponding to each sequential disc, a random-order disc was prepared. There were thus a total of six discs used.

Table 28

Mean Time and Mean Number of Responses to Complete Discs a, b and c.

	Disc a		Disc b		Disc c	
	Random	Sequential	Random	Sequential	Random	Sequential
Time (In minutes)	20.4	20.7	16.3	16.6	33.4	29.3
Number of Responses	41	42	39	40	49	49
N	4	6	9	12	6	5

The mean time for the sequential discs was 25.0 minutes, and for the random, 25.7 minutes. The mean number of responses for the sequential is 42, and for the random, 43.

Each S was presented with two discs, both of which were either random or sequential. Some Ss received discs a and b, others received discs b & c. Ss worked on the second disc immediately after completing the first disc. On all discs Ss worked to the "no-error" criterion. For each disc completed by S the following data were recorded:

1. Time to complete a "no-error" run.
2. Total number of responses to complete a "no-error" run.

At the conclusion, Ss were asked to fill out a protocol (Appendix M).

SUBJECTS

A total of 21 Ss were selected from male and female students in the School of Liberal Arts of Brooklyn College.

RESULTS

Table 28 on the preceding page lists the mean time to complete the disc and the number of responses for each of the six discs.

Results showed that average time per disc would be about 25 minutes, with no difference between the sequential and random order.

It was felt that the level of sophistication of the Ss was higher than expected, and that it might be advisable to teach a more advanced body of material.

The answers to the protocols indicated no excessive negativism towards the machine on the part of Ss. Most Ss believed they had learned some new material. Many of them felt that the experiment served as a good review.

APPENDIX H

Programming

Programming for the experiment was undertaken with the guidance of two aids furnished by the contracting agency:

1. Two volumes of a four volume manual prepared by the Bureau of Naval Personnel entitled: "Basic Electricity".

2. Some sample programmed discs.

The manual was employed as a source-book for materials to be taught and the sample disc was used as a model in developing the actual programming techniques, e.g., size of increments, cueing, review, introduction of new material, structure of sentences, type of response to be elicited, etc.

As a preliminary trial, for purposes of orienting the direction of the experiment, 60 questions (2 discs) were prepared covering the first two topics in the manual: "What Electricity Is" and "How Friction Produces Electricity." Initial trial experiments disclosed that the proportion of correct responses was too high and it was concluded that the subject matter was rather elementary for our population. It was then decided that more advanced material would be used. Decision on the specific body of material to be presented involved consideration of a number of factors. First, it was desired that the material be of such degree of sophistication that very few of the Ss would be already familiar with all the material. Second, the material had to be manageable by naive Ss. Third, the amount of material should allow Ss to complete the learning session in a reasonable length of time. Fourth, it was desired that the material permit tests of rote memory and in addition, test the Ss ability to apply what he had learned to new problem situations.

On the basis of the above considerations, it was decided to teach enough pertinent material to enable Ss, after training, to solve a series-parallel direct current circuit. This meant that the following concepts would have to be mastered: basic definitions and symbols, Ohm's Law, operation of a battery, voltages and resistances in series, voltage drop, Kirchhoff's Laws, parallel circuits and finally, solution of series-parallel circuits.

Initial programming revealed that approximately 160 items would be needed which amounted to 10 items greater than could be accommodated on 5 discs. However, information obtained during the preliminary experiment indicated that 5 discs was an impractical length of treatment. Further, it was felt that the programming for the final section of the material (solution of series-parallel circuits) was not entirely satisfactory because exposition of such complex problem-solving techniques requires that the S follow closely a rather extended train of thought and reasoning. The teaching machine, however, is so constructed as to make such presentation difficult since only one item is shown at a time and cross-references or back-referrals are impractical. In view of these facts, two changes were adopted. First, basic definitions and symbols were eliminated from the program and presented in text form as pre-learning material; that is, as material to be learned before presentation of information through the teaching machine. Second, the final section of the material was scaled down to include only the solution of very simple series-parallel DC circuits. As a result of these changes, the program now consisted of pre-learning material plus 120 items (4 discs).

When the experiments were conducted on this basis, another difficulty was encountered: the scheduling of Ss. It was considered inadvisable to ask Ss to complete all four discs in one sitting for two reasons: 1) There would be a problem in finding Ss who could fit such a lengthy session into their personal schedule. 2) There was doubt that Ss attention could be held over such a span. The next possibility was the scheduling of two sessions of two discs each. It was found that Ss could not arrange sessions so that all had equal lapses of time between the two sessions. It was finally decided to use one session of approximately $2\frac{1}{2}$ - 3 hours and to reduce the material to the first two discs. The two discs covered the following topics: Ohm's Law, series circuits, operations of a battery and voltage drop.

The pre-learning material included a simple textual explanation of the nature of electricity, definition of an electrical circuit, and definitions, abbreviations, units and symbols for current, EMF and resistance. Originally, a paragraph on operation of a battery had been included in the pre-learning material for the four disc program. When the design was changed to two discs, however, this was deleted because it duplicated material in the program. It was thought advisable to maximize the amount of material taught only through the machine.

Since an understanding of electrical circuits relies heavily on the use of diagrams and schematic representation, it was decided to prepare a set of diagrams on 5" by 7" index cards to be used in conjunction with the teaching machine. These were indexed numerically with the same number as the item to which they referred. The item on the disc was prefixed by the instruction: "see diagram #______" so that S could turn to the appropriate diagram while reading the item in question.

In the actual preparation of the items, the programmer used the disc supplied by the contracting agency as a model. For this reason, the completion type of item was prepared first. The first section of the program was devoted to a review of the pre-learning material. Ohm's Law was then introduced, simple analogies were used liberally and the Law applied to the solution of elementary circuits. Next, the concept of resistances in series was presented; finally, the internal operation of a battery. Voltage drop was not emphasized as a distinct body of material but distributed among the other topics. It was developed more fully in connection with Kirchhoff's Law, which does not appear on discs numbers 1 and 2, but which was a part of the programming on discs numbers 3 and 4.

GENERAL TECHNIQUES OF PROGRAMMING

1. Review items were employed throughout the program to repeat previously presented material upon which new material was based. Sometimes the review was merely stated as an ancillary part of the item, and sometimes the review response was called for.

2. In introducing new material "give-away" questions were used. In all other items, however, S was required to make the crucial response to the item.

3. Much of the material included the numerical solution of problems. In view of this, the program was designed so as to make very small demands on the mathematical ability of the Ss. This was achieved by stating the formula verbally and then progressing to the symbolic formula itself. After this, the different algebraic forms of the formula were presented followed by arithematic substitution and solution.

4. As a matter of economy, some items called for more than one response. In no instance, however, did this represent more than one new bit of information. In scoring such items, S was instructed that all parts had to be correct.

5. Every effort was made to keep the incremental steps between items the same size and rate as the furnished model. An analysis of the 60 items on the two disc categorizes them as follows:

Subject Matter	Number of Items
Review of Pre-Learning	12
Introduction to Ohm's Law	8
Statement on formula of Ohm's Law	13
Numerical application of Ohm's Law	14
Concept of Voltage Drop	6
Series Connection	11
Internal operation of a battery	11
Total	75

The total exceeds 60 because many items combine two of more of the above concepts in a single item.

In programming the material for multiple choice and true and false treatments, the identical items and diagrams as developed for the completion treatment were used. The item was merely worded in accordance with the desired treatment form, but the sense and content of the item was not altered. In the case of multiple choice, the physical space limitation of the disc which must be used in the Skinner machine made it impossible to offer the S four response choices, a standard practice in the field. Despite the use of special small size type, the limited space on the disc permitted the maximum use of approximately 40 words per item. Consequently it was necessary to offer S only three response choices.

In the case of multiple choice and true-false treatments no more than one response was asked for in any given item. This led to a slight weakening of the program in the case of the true-false treatment. As stated previously, many items contained more than one information "bit". Since the true-false treatment called for one answer only, this answer had to refer to the whole item. If, therefore, an answer to a "multi-bit" item was false, S could not tell which part of the item was incorrect. This disadvantage is, of course, characteristic of true-false devices generally.

One small deviation from the original completion treatment was made in the multiple choice treatment (but not in true-false). Item number 51 was changed from an item relating to direction of current flow to an item involving two batteries in series. This was done in order to find out whether the concept of EMF in series could be strengthened in S. This concept is tested for in the examinations. This test item was designed to check "transfer learning." But preliminary investigation of exam results showed very little transfer taking place. This change was made to determine whether learning would improve.

In presenting the material in lecture form the lecturer attempted to simulate, as closely as possible, the customary classroom situation. The lecture was developed so as to cover the same subject matter, in the same sequence and using the same pedagogic devices - analogies, review, sample calculation, etc., as used in the item material programmed for the teaching machine. The class was permitted to ask questions and these were answered by the instructor. It was also suggested to the class that they might employ any study habits they wished: taking notes, etc., during the lecture. In answering class questions the instructor was careful not to amplify any points beyond the levels of the programmed machine items.

Again, in preparing the material as text, the original machine programs were followed as to content and sequence. However, full advantage was taken of the fact that textual material lends itself more readily to the exposition of extended but related sequences of thought.

Using the above-described machine program, a cursory investigation of experiment test results showed rather poor performance on exam questions relating to voltage drop. Interrogation of Ss who had already completed the experiment and had done poorly on voltage drop did indeed reveal that they had not grasped the fundamental concept of voltage drop. A review of the programming revealed that there might be two possible reasons for this:

1. The fact that unlike other material voltage drop had not been presented as a closely unified body of material. This was a fortuitous circumstance, since, as was mentioned earlier, the programming had originally been developed for four discs with voltage drop further considered on discs numbers 3 and 4. When, however, exigencies compelled the teaching program to be reduced to the first two discs, the presentation of voltage drop was weakened.

2. Detailed analysis of the items involving voltage drop, revealed that despite the fact that all items gave information about voltage drop, only two of them required that S employ voltage drop actively in making the response. For instance, item number 24 reads:

   "The reduction in EMF as a result of pushing a current through a _____ is called the voltage drop. Voltage drop equals the product of $\overline{\text{I x R}}$ (resistance.")

   The correct response "resistance" can be made by S without paying any attention to the information relative to voltage drop. It was therefore hypothesized that Ss strongest motivation is not to learn the material but rather to answer the item correctly. Hence information in an item which is not actively used to arrive at an answer, is not given equal attention and thus is not learned as well. On the basis of the above hypothesis, new programs were prepared which fit into the arbitrarily improved limitations of 60 items (two discs) and which reorganized the material relative to voltage drop into a unified structure. This new program could not be incorporated into the experimental design, however, because a good number of the groups had already been tested and it was deemed prejudicial to change the experiment in midstream. Further, time did not permit a complete re-run of the experiment using the new program. It should be borne in mind, however, that although it is believed that the new program is superior, the use of the original program in no way impugns the validity and usefulness of the experiment as actually run. The question of superiority is naturally a moot one and subject to experimental verification. For instance, the new program reduces the number of review items and, at times, employs larger incremental steps. It may be that such changes would yield less satisfactory results.

APPENDIX H

Completion Items Programmed for the Skinner Teaching Machine

1. An electrical circuit exists wherever two conditions are fulfilled: a) a complete path for flow of electrons; b) a source of electromotive force. If either of these is missing we do not have an electrical______.	(circuit)
2. The rate at which electrons flow past a given point on a circuit is called current. The faster the electron flow, the______the current.	(greater)
3. In any electrical circuit three quantities are always present: electromotive force (abbr. EMF), resistance, and______.	(current)
4. The unit of measurement for current is amperes. Amperes indicate how many______flow past some point in a given time.	(electrons)
5. The three units of measurement always associated with a circuit are: ohms for resistance, volts for electromotive force (EMF),______for current.	(Amperes)
6. In driving a nail into a piece of wood, the depth of penetration depends on two things: the force of the hammer blow and the resistance of the______.	(wood)
7. In operating a motor boat, the speed depends on a) the driving force of the_____ and b) the resistance of the water.	(engine; motor; propellor)
8. In operating a flashlight, the electron flow (current) depends on a) the EMF of the______ and b) the resistance of the light bulb.	(battery)
9. If a heavier hammer is used in driving a nail, it will penetrate deeper. Similarly, if a battery of increased EMF is placed in a circuit, the current will______.	(increase)

10. If a motor boat suddenly encounters rough water, the increased resistance will slow it down. By analogy, if the resistance in a circuit is increased, the flow of current is__________. (reduced; smaller)

11. If in a circuit we wish to increase the current flow, the_____must be increased. (EMF)

12. If the resistance in a circuit is increased, it is necessary to_____the EMF in order to maintain the same current flow. (increase)

13. Current will increase if EMF is greater. ~~Conversely,~~ current will_____if resistance is greater. (decrease)

14. In any electrical circuit there is an interdependence among EMF, resistance, and_____. The mathematical relationship betseen current, _____, and resistance is known as Ohm's Law. (current; EMF)

15. Ohm's Law states that current is directly proportional to EMF but inversely proportional to_____. (resistance)

16. In symbols, Ohm's Law is written I = E/R when I must be expressed in ameperes, E in _____ and R in ohms. (volts)

17. Ohm's Law can be written in another form by rearranging it algebraically. Thus, E = I x R is merely another statement of_______. (Ohm's Law)

18. Expressed in units, Ohm's Law E = I x R can be written as volts =_____ x ohms. (amperes)

19. According to Ohm's Law, it requires _____ volts to push 2 amperes through a resistance of 3 ohms. (6 volts)

20. If we wish to double the current through a resistance, the EMF must be______. (doubled)

21. If we wish to double the current in a circuit and the resistance is halved, the EMF should be______. (unchanged)

22.	(See diagram No. 22) In the circuit shown E represents the electromotive force (EMF) of a battery, I represents the current, and R should be ______ volts.	(30 volts)
23.	An electromotive force of ______ volts is expended in pushing $\frac{1}{2}$ amperes through a resistance of 8 ohms.	(4 volts)
24.	The reduction in EMF as a result of pushing a current through a ______ is called the voltage drop. Voltage drop equals the product of I x R.	(resistance)
25.	Ohm's Law (I = E/R) is valid only if all quantities are exposed in their proper basic units. Thus, 4 ______ = 32 volts/ ______ ohms.	(amperes; 8 ohms)
26.	The EMF in a circuit is 10 volts and the R = 50 ohms. The current equals______.	(1/5 ampere)
27.	(See diagram No. 27) The current I = ______ amperes.	($\frac{1}{2}$ ampere)
28.	Ohm's Law can also be used to find resistance if both EMF and current are known. Thus, E = IR can be arranged to R = _____/_____.	(R = E/I)
29.	If an EMF of 6 volts results in a current of 2 amps through a resistance, R = _______.	(3 ohms)
30.	(See diagram No. 30) R = _______.	(6 ohms)
31.	If there are both a source of EMF and a complete path for the flow of electrons, an electrical ______ exists.	(circuit)
32.	Ohm's Law relates mathematically the current flow through a resistance resulting from an ______ acting on it.	(EMF)
33.	Voltage drop (abbr. V) represents the expenditure of EMF in pushing _______ through a resistance.	(current; electrons)
34.	An EMF of _____ volts is required to produce a current of 3 amps through a resistance of 5 ohms.	(15 volts)
35.	(See diagram No. 35) Another form of ____ is R = E/I. In the circuit shown, R = ________.	(Ohm's Law) ($\frac{1}{2}$ ohm)

36.	(see diagram No. 36) still another form of Ohm's Law is I =_____. In the diagram, I_a =_____amps.	(E/R) (10 amps)
37.	(See diagram No. 37) A circuit sometimes includes more than one resistance. If the resistances are connected end to end in chain fashion it is called a series connection. The diagram shows two resistances connected in_____.	(series)
38.	If two resistances are connected in series, all the_____flowing through the first resistance also flows through the second.	(current; electrons)
39.	(See diagram No. 39) The circuit shows the two resistances series connected. Hence, there is only one path for current flow. If I_a and I_b represent the current through resistances R_a and R_b respectively, I_a must_____I_b.	(equal)
40.	If two resistances are connected together so that the same current flows through each, it is a_____connection.	(series)
41.	(See diagram No. 41) The sketch shows a series circuit because all the current through R_a flows successively through R_b and R_c. If I_a = 7.5 amps, then the value of I_b =_____ and I_c =_____.	(7.5 amps; 7.5 amps)
42.	(See diagram No. 42) The same current must flow through R_a, R_b and R_c. Hence they are_____.	(series connected)
43.	(See diagram No. 43) Of the four resistances shown, only two are series connected because all the current through one flows through the other. Those are resistances_____and_____.	(R_c; R_d)
44.	There is a drop in voltage (V) associated with pushing I amperes through a resistance of R ohms. From_____Law we can calculate this voltage drop since V = IR.	(Ohm's)
45.	A current of 4.5 amperes flows through a 2 ohm resistance. The loss in EMF represented by the voltage drop equals_____volts.	(9 volts)

46. (See diagram No. 46) The diagram shows a series cct. since there is only one path for current flow. We know that the current is the same in resistances _____and_____.

(R_a; R_c)

47. (See diagram No. 47) In the circuit sketched, the voltage drop (V_b) through resistance B is known to be 10 volts. The current through R_b is then_____. Further, since this is a_____circuit, $I_b = I_a = I_c$.

(20 amps; series)

48. (See diagram No. 48) In the series cct. shown, it is known that the voltage drop V_a through R is 6 volts. The voltage drop through resistance B is then_____.

(15 volts)

49. In any circuit two conditions must be present: a complete path for flow of electrons, and a source of EMF. In a_____circuit, one additional condition is present: the current through each element in the circuit is the same.

(series)

50. Current in a circuit flows from_____of electrons to the_____of electrons.

(excess; lack)

51. (See diagram No. 51) In the symbol for a battery, the long line represents the excess of electrons. In the circuit drawn, direction of I_a is from _____to_____.

(Left to right;
R_a to R_b)

52. If an object has an_____of electrons, it has a negative charge. If it has a_____of electrons, it has a positive charge.

(excess; lack)

53. (See diagram No. 53) The battery shows the "excess" side (or terminal) and "lack" terminal. When current flows,_____leave the excess terminal and arrive at the _____.

(electrons;
lack terminal)

54. (See diagram No. 54) If electrons are allowed to accumulate at the lack terminal, they will neutralize the charges and an electron deficiency will no longer exist; as a result, no_____will flow.

(current; electrons)

55. (See diagram No. 55) A battery, by internal chemical action, continaully transfers electrons from lack to excess terminal so that a_____in charge always exists.

(difference;
unbalance)

56. A battery is constructed so that it can transfer electrons in only one direction: that is, the free electrons always appear at the excess terminal. This is why current in a circuit always flows from_____to_____terminal.

(excess; lack)

57. When a battery transfers electrons from one terminal to the other it creates the_____ force essential for making current flow in a set.

(electromotive)

58. The EMF or voltage of a battery is a measure of how rapidly electrons are being transferred from lack to excess terminal. The faster the transfer, the_____the EMF.

(greater; higher)

59. If we wish to double the EMF in a circuit, we can replace the existing battery by one that transfers electrons_____as fast.

(twice)

60. The EMF of a circuit can also be doubled by adding to the circuit a second battery whose EMF______the first one.

(equals)

Multiple Choice Items Programmed for the Skinner Teaching Machine

1. An electrical circuit exists whenever two conditions are fulfilled: a complete path for flow of electrons and a source of ______. a) voltage drop b) electromotive force c) resistance. (b)

2. The rate at which electrons flow past a given point on a circuit is called the current. The faster the flow, the ______ the current. a) greater b) smoother c) smaller (a)

3. In any electrical circuit three quantities are always present: electromotive force (EMF), resistance, and ______ a) current b) capacitance c) grid reactance. (a)

4 The unit of measurement for current is amperes. Amperes indicate how many ______ flow past some point in a given time. a) coulombs b) electrons c) nuclei. (b)

5. The three units for measurement always associated with a circuit are: ohms for resistance, volts for electromotive force, ______ for current. a) kilowatts b) amperes c) potential. (b)

6. In driving a nail into a piece of wood, the depth of penetration depends on two things: the force of the hammer blow and the resistance of the ______. a) nail b) carpenter c) wood (c)

7. In operating a motor boat, the speed depends on the driving force of the ______ and the resistance of the water. a) skipper b) propeller c) gross weight (b)

8. In operating a flashlight, the current depends on the ______ of the battery and the resistance of the light bulb. a) EMF b) age c) temperature. (a)

9. If a heavier hammer is used in driving a nail, it will penetrate deeper. Similarly, if a battery of increased EMF is placed in a circuit, the current will ______. a) increase b) decrease c) double. (a)

10. If a motor boat suddenly encounters rough waters, the increased resistance will slow it down. By analogy, if the resistance of a circuit is increased, the flow of current is ______. a) reduced b) cut off c) greater. (a)

11. If a circuit we wish to increase the current flow, the ______ must be increased. a) EMF b) resistance c) insulation. (a)

12. If the resistance in a circuit is increased, it is necessary to increase the_____in order to maintain the same current flow.
a) amperage b) wire c) EMF. (c)

13. Current will increase if EMF is greater. Conversely, current will _____if resistance is greater. a) cease b) become irregular c) decrease (c)

14. In any electrical circuit there is a mathematical relationship among EMF, current and _____. This relationship is known as Ohm's Law.
a) ohms b) resistance c) electromotive force. (b)

15. Ohm's Law states that current is directly proportional to EMF but inversely proportional to_____. a) resistance b) voltage drop
c) ohms. (a)

16. In symbols, Ohm's Law is written I = E/R when I must be expressed in amperes, E in _____ and R in ohms. a) coulombs b) volts c) EMF. (b)

17. Ohm's Law can be written in another form by rearranging it algebraically as follows: E = _____. a) I/R b) R/I c) IR. (c)

18. Expressed in units, Ohm's Law, E = IR can be written as volts = _____x ohms. a) current b) electron flow c) amperes (c)

19. According to Ohm's Law, it requires_____volts to push two amperes through a resistance of three ohms. a) 6 b) 1.5 c) 2/3. (a)

20. If we wish to double the current through a resistance, the EMF must be _____ if the resistance is halved. a) unchanged b) doubled
(c) halved. (a)

21. If we wish to double the current in a circuit and the resistance is halved, the EMF should be _____. a) unchanged b) doubled
c) halved. (a)

22. In the circuit shown (See diagram No. 22) E represents the electromotive force of a battery, I represents the current and R the resistance. The EMF of the battery should be _____
volts. a) 30 b) 3 1/3 c) 3/10. (a)

23. An electromotive force of _____ volts is expended in pushing ½ ampere through a resistance of 8
ohms. a) 16 b) 4 c) 8 (b)

24. The reduction in EMF as a result of pushing a current thru a_____is called the voltage drop.
Voltage drop equals the production of IR
a) battery b) voltometer c) resistance (c)

25. Ohm's Law (I = E/R) is valid only if all quantities are expressed in their proper basic units. Thus 4_____ = 32
volts/8 ohms. a) amperes b) watts c) volts (a)

26. The EMF in a circuit is 10 volts and the R = 50 ohms. The current equals_____. a) 500 amperes b) 1/5 ampere c) 5 amperes (b)

27. (See diagram No. 27) The current I = _____ amperes. a) ½ b) 32 c) 2 (a)

28. Ohm's Law can also be used to find resistance, if both EMF and current are known. Thus E - IR can be rearranged to R = _____. a) R - I/E b) R - IE c) R = EI (a)

29. If an EMF of 6 volts results in a current of 2 amps through a resistance, R = _________. a) 3 ohms b) 12 ohms c) 1/3 ohms (a)

30. (See diagram No. 30) R = ________. (a)

31. If there are both a complete path for flow of electrons and a source of _____, an electrical circuit exists. a) voltage b) EMF c) resistance (b)

32. _____ relates the current through a resistance to the EMF acting on the resistance. a) Potential theory b) Electromagnetism c) Ohm's Law (c)

33. Voltage drop (abbreviated V) represents the expenditure of EMF in pushing _____ through a resistance. a) current b) volts c) ions (a)

34. A voltage drop of _____ volts results from pushing 3 amperes through a resistance of 9 ohms. a) 3 b) 27 c) 1/3 (b)

35. (See diagram No. 35) Another form of Ohm's Law is R = E/I. In the circuit shown, R - __________. (b)

36. (See diagram No. 36) Still another form of Ohm's Law is I - ER. In the diagram, I_a = a) 10 b) 1000 c) 1/10 (a)

37. (See diagram No. 37) A circuit sometimes includes more than one resistance. If the resistances are connected end to end in chain fashion, it is called a series connection. The diagram shows them connected in a) parallel b) series c) closed (b)

38. If 2 resistances are connected in series, all the _____ flowing through the first resistance also flows through the second. a) current b) voltage c) power (a)

39. (See diagram No. 37) Resistances A & B are series connected so that there is one path for current flow. Current in A_____current in B. a) less than b) greater than c) is equal to (c)

40. If two resistances are connected together so that the same current flows thru each, it is a) ______ connection. a) circuit b) series c) closed (b)

41. (See diagram No. 41). The sketch shows a series circuit so that I_a, I_b and I_c are all equal. Voltage drop thru A is ______ voltage drop through B. a) smaller than b) greater than c) equal to (a)

42. (See diagram No. 42). The same current must flow thru R_a, R_b and R_c. The resistances are ______. a) all equal b) series connected c) line connected. (b)

43. (See diagram No. 43) Of the four resistances shown, only two are series connected because all the current thru one flows thru the other. These two are resistances ______ and ______. a) R_a and R_d b) R_b and R_c c) R_c and R_d (c)

44. Both E and V are expressed in volts. The first symbol stands for electromotive force, while V is an abbreviation for ______. a) Ohmic loss b) voltage drop c) diamagnetic voltage (b)

45. Four amperes flow through a two ohm resistance. This results in a voltage drop of ______ volts. a $\frac{1}{2}$ b) 2 c) 8 (c)

46. (See diagram No. 46) The diagram shows a series circuit since there is only one path for current flow. We know that the current is the same in resistance ______and______. a) A and C b) A and B c) B and C (a)

47. (See diagram No. 47) In the series circuit shown the voltage drop (V_b) thru resistance B is 10 volts so that I_b is 20 amps. I_a = (b)

48. (See diagram No. 48). In the series circuit shown, it is known that the Voltage drop thru R_a is 6 volts. The voltage drop thru resistance B is then ______. a) 15 volts b) indeterminate c) 6 volts (a)

49. Any circuit must contain a complete path for electron flow and a source of EMF. A series circuit includes one additional condition: the ______thru each element in the circuit is the same. a) current b) resistance c) voltage drop (a)

50. Current in a circuit flows from excess to lack ______. a) charge b) amperes c) terminal (c)

51. If two batteries are connected in series, the total EMF is _____ of the two EMFs. a) the product b) the sum c) one half (b)

52. (See diagram No. 52). The battery shows the "excess" side (or terminal and "lack" terminal. When current flows, _____ leave the excess terminal and arrive at the lack terminal. a) electrons b) protons c) atons (a)

53. (See diagram No. 53). In the circuit shown, the current is _____ amps. a) 25 b) 1 c) zero (b)

54. (See diagram No. 54). If electrons accumulate at the lack terminal, they will neutralize the plus charges and an electron deficiency will _____ there. As a result, no current will flow. a) no longer exist b) develop c) ionize (a)

55. (See diagram No. 55). A battery, by internal chemical action, continually transfers electrons from lack to excess terminal so that _____ in charge always exists between terminals. a) a reduction b) a difference c) an equality (b)

56. A battery is constructed so that it can transfer electrons in only one direction, that is, the free electrons always appear at the _____ terminal. a) lack b) junction c) excess (c)

57. When a battery transfers electrons from one of its terminals to the other, it uses chemical force to create _____ force for use in a circuit. a) electromotive b) magnetic c) an opposing (a)

58. The EMF or voltage of a battery is a measure of how rapidly electrons are being transferred from the lack to the excess terminal. The faster the transfer, the _____ the EMF. a) greater (b smaller c) faster (a)

59. If we wish to double the EMF in a circuit we can replace the existing battery by one that transfers electrons _____ as fast. a) almost b) twice c) ½ (b)

60. A circuit contains a 6 volt battery. The EMF in the circuit can be doubled by adding a _____ volt battery in series with the first. (a 12 b) 6 c) 3 (b)

True-False Items Programmed for the Skinner Teaching Machine

1. An electrical circuit exists when the following two conditions are fulfilled a) complete path for flow of electrons and b) a source of electromotive force. (true)
2. The rate at which electrons flow past a given point on a circuit is called current. The faster the electrons flow the higher the current. (true)
3. In any electrical circuit three quantities are aways present: electromotive force (EMF), resistance, and current. (true)
4. The unit of measurement for current is amperes. Amperes indicates how many volts flow past some point in a given time. (false)
5. The three units of measurement always associated with a circuit are: ohms for resistance, volts for EMF and watts for current. (false)
6. In driving a nail into a piece of wood, the depth of penetration depends on two things: the force of the hammer blow and the resistance of the wood. (true)
7. In operating a motor boat, the speed depends on a) the driving force of the propeller and b) the resistance of the water. (true)
8. In operating a flashlight, the electron flow (current depends on a) the EMF of the battery and b) the resistance of the light bulb. (true)
9. If a heavier hammer is used in driving a nail, it will penetrate deeper. Similarly, if a battery of increased EMF is placed in a circuit, the current will increase. (true)
10. If a motor boat suddenly encounters rough waters, the increased resistance will slow it down. By analogy, if the resistance of a circuit is increased, the flow of current is reduced. (true)
11. If in a circuit we wish to increase the current flow, the resistance must be increased. (false)

12. If the resistance in a circuit is increased, it is increased, it is necessary to decrease the EMF in order to maintain the same current flow. (false)

13. Current will increase if EMF is greater. Conversely, current will decrease if resistance is greater. (true)

14. In any electrical circuit there is an interdependence among EMF, resistance and current. The mathematical relationship between current, EMF and resistance is known as Ohm's Law. (true)

15. Ohm's Law states that current is directly proportional to EMF and resistance. (false)

16. In symbols, Ohm's Law is written $I = E/R$ when I must be expressed in amperes, E in volts and R in Ohms. (true)

17. Ohm's Law can be written in another form by rearranging it algebraically. Thus, $R = EI$ is merely another statement of Ohm's Law. (false)

18. Expressed in units, Ohm's Law, $E = IR$ can be written as volts = amperes x ohms. (true)

19. According to Ohm's Law, it requires 6 volts to push 2 amperes through a resistance of 3 ohms. (true)

20. If we wish to double the current through a resistance, the EMF must be halved. (false)

21. If we wish to double the current in a circuit and the resistance is halved, the EMF should be unchanged. (true)

22. See diagram No. 22) In the circuit shown, E represents the electromotive force (EMF) of a battery, I represents the current, and R the resistance. The EMF of the battery should be 30 volts. (true)

23. An electromotive force of 16 volts is expended in pushing $\frac{1}{2}$ ampere through a resistance of 8 ohms. (false)

24. The reduction in EMF as a result of pushing a current through a resistance is called the voltage drop. Voltage drop equals the product of RI. (true)

25. Ohm's Law ($I = E/R$) is valid only if all quantities are exposed in their proper basic units. Thus, 4 amperes = 32 ohms/8 volts. (false)

26. The EMF in a circuit is 10 volts and the $R = 50$ ohms. The current equals 5 amperes. (false)

27. (See diagram No. 27) The current $I = \frac{1}{2}$ amps. (true)

28. Ohm's Law can also be used to find resistance, if both EMF and current are known. Thus $E = IR$ can be rearranged to $R = E/I$. (true)

29. If an EMF of 6 volts results in a current of 2 amps through a resistance, $R = 12$ ohms. (false)

30. (See diagram No. 30) $R = 6$ ohms. (true)

31. If there are both a source of resistance and a complete path for flow of electrons, an electrical circuit exists. (false)

32. Kirchoff's Law relates mathematically the current flow through a resistance resulting from an electromotive force acting on it. (false)

33. Voltage drop (abbreviated V) represents the expenditure of EMF in pushing current through a resistance. (true)

34. An EMF of 15 volts is required to produce a current of 3 amperes through a resistance of 5 ohms. (true)

35. (See diagram No. 35) Another form of Ohm's Law is $R = E/I$ in the circuit shown, $R = \frac{1}{2}$ ohm. (true)

36. (See diagram No. 36) Still another form of Ohm's Law is $I = E/R$. In the diagram, $I_a = 10$ amps. (true)

37. (See diagram No. 37) A circuit sometimes includes more than one resistance. If the resistances are connected end to end in chain fashion it is called a series connection. The diagram shows two resistances connected in series. (true)

38. If two resistances are connected in series, all the electrons flowing through the first resistance also flow through the second. (true)

39. (See diagram No. 39) The circuit shows the two resistance series connected. Hence, there is only one path for current flow. If I_a and I_b represent the current through resistances R_a and R_b respectively, I_a must be greater than I_b. (false)

40. If two resistances are connected together so that the same current flows through each, it is a parallel connection. (false)

41. (See diagram No. 41) The sketch shows a serier circuit because all the current through R_a flows successively through R and R . If $I_a = 7.5$ amps, then the value of $I_b = 7.5$ amps and $I_c = 15$ amps. (false)

42. (See diagram No. 42) The same current must flow through R_a, R_b, and R_c. Hence they are series connected. (true)

43. (See diagram No. 43) Of the four resistances shown, only two are series connected because all the current through one flows through the other. These two are resistances R_a and R_b. (false)

44. There is a drop in voltage (V) associated with pushing one ampere through a resistance of R Ohms. From Ohm's Law we can calculate this voltage drop, since $V = IR$. (true)

45. A current of 4.5 amperes flows through a 2 ohm resistance. The loss in EMF represented by the voltage drop equals 9 volts (true)

46. (See diagram No. 46) The diagram shows a series circuit since there is only one path for current flow. We know that the current is the same in resistances A and C. (true)

47. (See diagram No. 47) In the circuit sketched, the voltage drop through resistance B is known to be 10 volts. The current through R_b is then 20 amps. Further, since this is a series circuit, $I_b = I_a = I_c$. (true)

48. (See diagram No. 48) In the series circuit shown, it is known that the voltage drop (V_a) through R_a is 6 volts. The voltage drop through resistance B is then 6 volts. (false)

49. In any circuit, two conditions must be present: a complete path for flow of electrons, and a source of EMF. In a series circuit, one additional condition exists: the voltage drop through each element in the circuit is the same. (false)

50. Current in a circuit flows from excess to lack of electrons. (true)

51. (See diagram No. 51) In the symbol for a battery the long line represents the excess of electrons. In the circuit shown, direction of I_a is from right to left. (false)

52 If an object has an excess of electrons it has a negative charge. If it has a lack of electrons it has a positive charge. (true)

53. (See diagram No. 53) The battery shows the "excess" side (or terminal) and "lack" terminal. The direction of current flow is opposite to that indicated by the arrows. (false)

54. (See diagram No. 54) If electrons are allowed to accumulate at the lack terminal they will neutralize the charges and an electron deficiency will no longer exist. As a result, no current will flow. (true)

55. (See diagram No. 55) A battery, by internal chemical action, continually transfers electrons from lack to excess terminal so that a difference in charge always exists. (true)

56. A battery is constructed so that it can transfer electrons in only one direction: that is, the free electrons always appear at the excess terminal. This is why current in a circuit always flows from excess to lack terminal. (true)

57. When a battery transfers electrons from one terminal to the other, it creats the electromotive force essential for making current flow in a circuit. (true)

58. The EMF or voltage of a battery is a measure of how rapidly electrons are being transferred from lack to excess terminal. The faster the transfer, the lower the EMF. (false)

59. If we wish to double the EMF in a circuit, we can replace the existing battery by one that transfers electrons four times as fast. (false)

60. The EMF of a circuit can also be doubled by adding to the circuit a second battery whose EMF is less than the first one. (false)

Diagrams Used With Programmed Machine in Experiment

DIAGRAM NO. 22

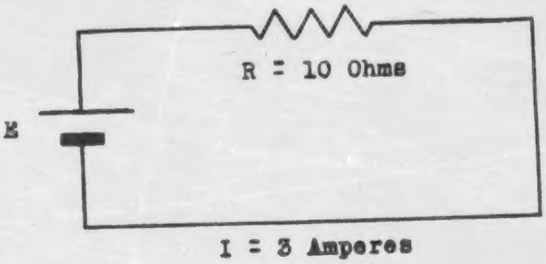

R = 10 Ohms
E
I = 3 Amperes

DIAGRAM NO. 27

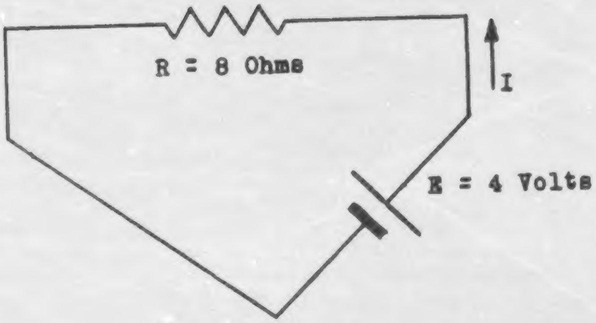

R = 8 Ohms
I
E = 4 Volts

DIAGRAM NO. 30

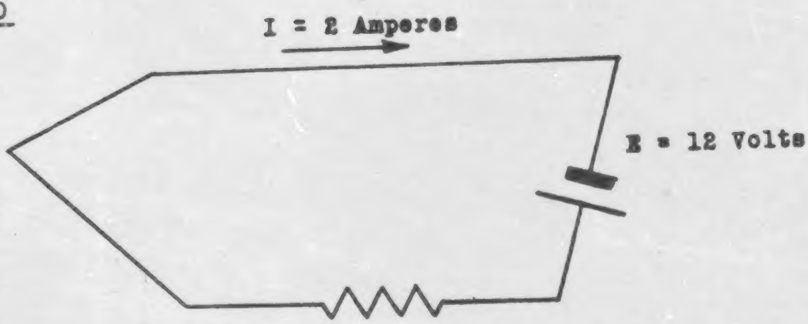

I = 2 Amperes
E = 12 Volts

DIAGRAM NO. 35

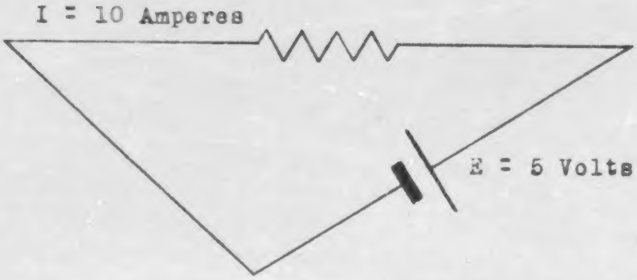

I = 10 Amperes
E = 5 Volts

DIAGRAM NO. 36

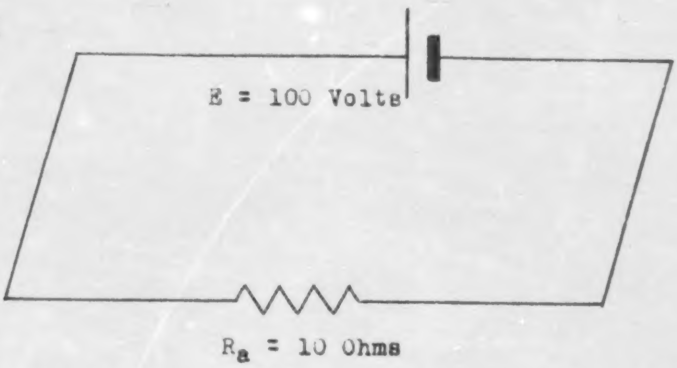

E = 100 Volts
R_a = 10 Ohms

DIAGRAM NO. 37

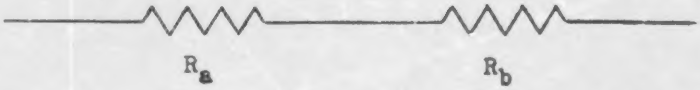


DIAGRAM NO. 39

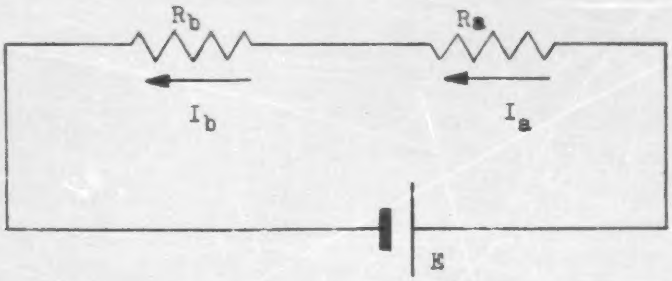


DIAGRAM NO. 41

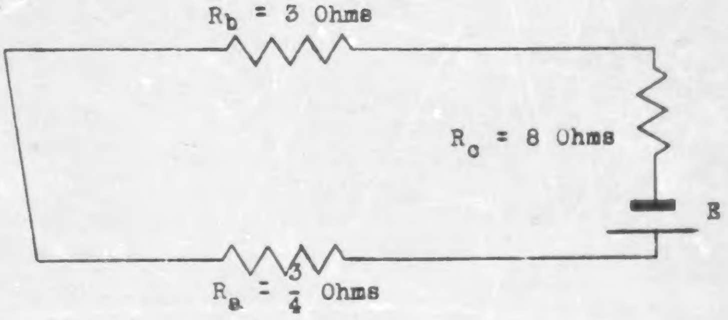
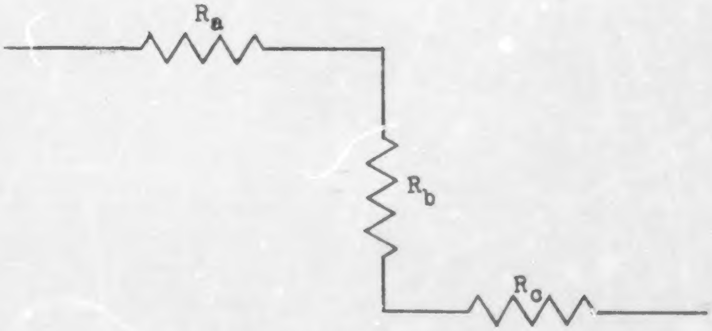

R_b = 3 Ohms
R_c = 8 Ohms
E
$R_a = \frac{3}{4}$ Ohms

DIAGRAM NO. 42



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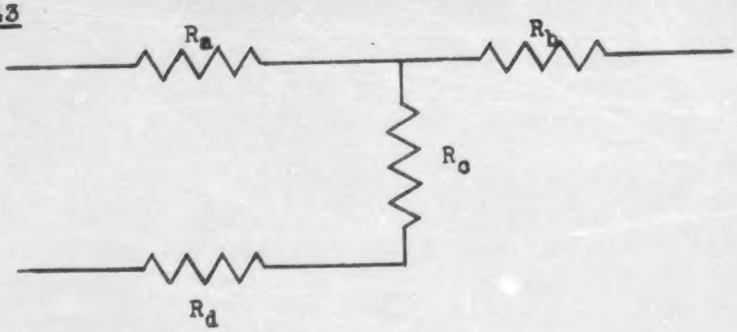

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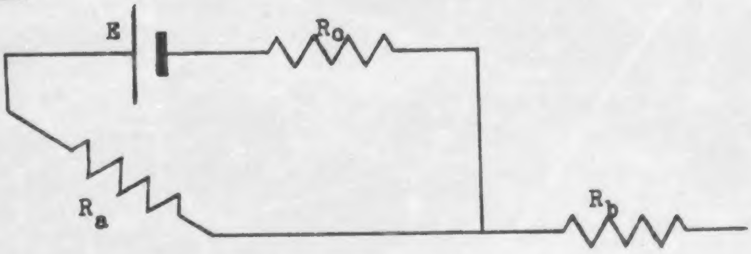

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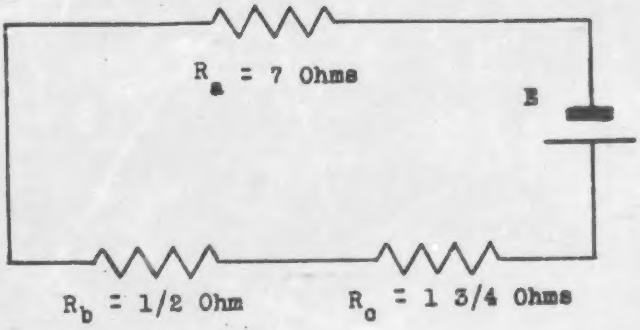
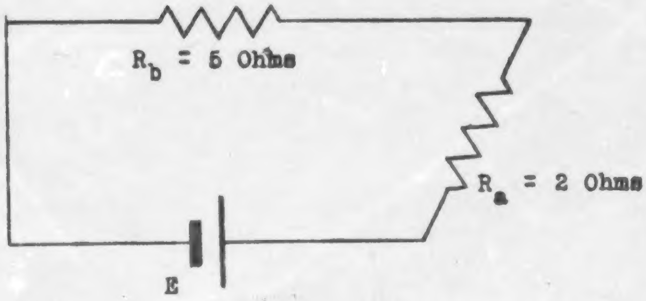

R_a = 7 Ohms
E
R_b = 1/2 Ohm
R_c = 1 3/4 Ohms

DIAGRAM NO. 48



R_b = 5 Ohms
R_a = 2 Ohms
E

DIAGRAM NO. 51

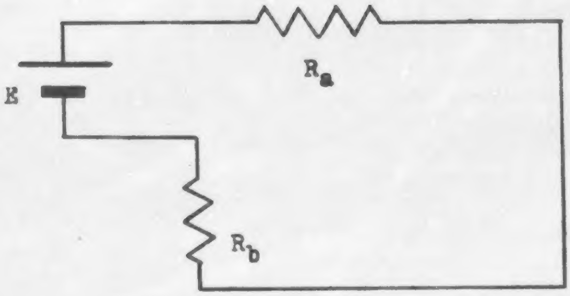
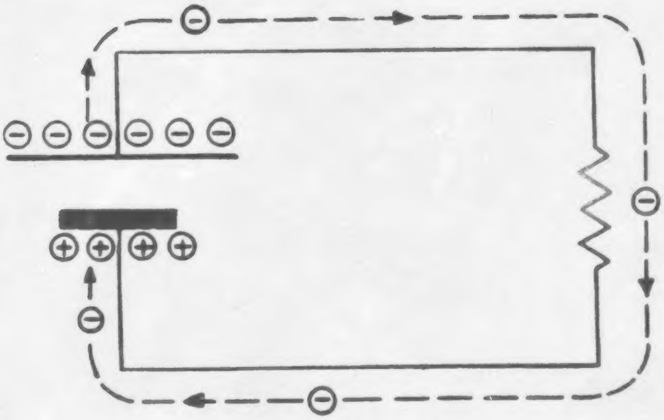


DIAGRAM NO. 53



69.

DIAGRAM NO. 54

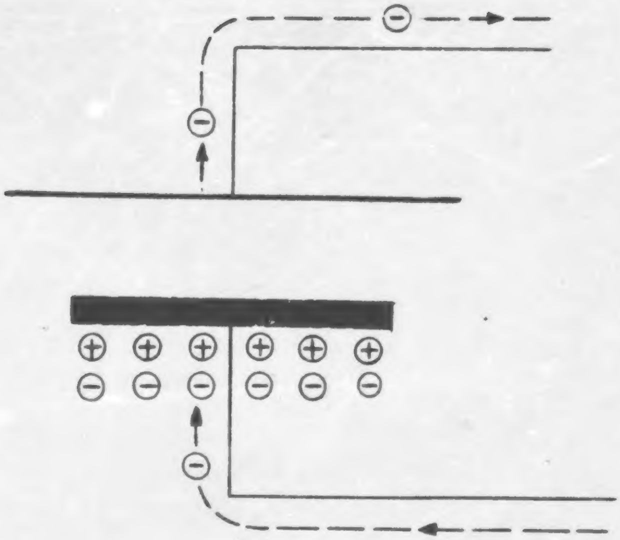
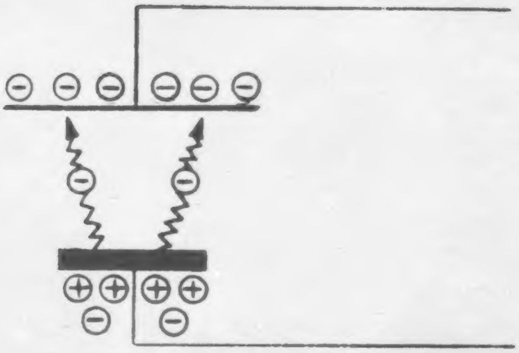


DIAGRAM NO. 55



Advanced Programmed Material for the Skinner Teaching Machine

Completion Items

61. Current in a circuit can be defined as the rate of flow of ______. The direction of flow through the circuit is always from the excess to the ______ terminal of a voltaged source. (electron; lack)

62. In order for current to continue flowing, there must always be a sufficient number of free electrons at the ______ terminal. (excess)

63. A battery uses internal chemical action to transfer electrons from its lack to its excess terminal. The speed with which it makes free electrons available is a measure of its ______ force. (electromotive)

64. (See diagram No. 64) Current in a circuit always moves from excess to lack terminal. Current inside a battery always moves from ______ to ______. (lack to excess)

65. Because the EMF in a battery appears only at the excess terminal, the ______ of current flow in a circuit will depend on which way the battery is connected into the circuit. This directional characteristic is called polarity. (directive)

66. If batteries are connected end to end, they are in series. Each contributes its individual EMF to the total EMF according to the direction (or ______) of the connection. (polarity)

67. EMF is added to a circuit when electrons are caused to accumulate at the ______ terminal. If two batteries are connected in series with the same polarity, the total EMF is the ______ of the two. (excess; sum)

68. If, on the other hand, two batteries are series connected so that the polarities "oppose" each other, the net EMF is the ______ of the two. (difference)

69. When batteries are series connected, the net resulting EMF depends on the ______ of the connection. If the same, they add. If opposite, they ______. (polarity; subtract)

70. (See Diagram No. 70) In the diagram all the polarities are the same. The net EMF is ______. (7 volts)

71. (See diagram No. 71) In the circuit shown, the polarity of one E_t = ______.

(E_a plus E_b minus E_c)

72. (See diagram No. 72) If batteries are series connected, the resulting direction of current is determined by the polarity of net EMF. In the circuit, E_t = ______. Direction of current through the resistance is from ______.

(2 volts; left to right)

73. (See diagram No. 73) In the circuit shown, E_t = ______. I_t = ______.

(14; 7)

74. (See Diagram No. 74) In the circuit E_t = ______. Voltage drop (V) through a resistance - current x resistance. For this circuit, V = ______.

(zero; zero)

75. A foghorn in a tugboat has a resistance of 2.1 ohms and requires 3.3 amperes in order to sound. It is necessary to connect ______ two volt batteries in series (with additive polarity) in order to operate the foghorn.

(four)

76. If both the value of a resistance and the voltage drop across it are known the current can be calculated by using ______.

(Ohm's Law)

77. In a circuit consisting of many resistances and batteries, the use of Ohm's Law is often inadequate for determining the ______ flow. We then make use of Kirchhoff's Circuit Law.

(current)

78. Kirchhoff's ______ Law says that in tracing around any electrical circuit, the sum of the EMFs must equal the sum of the voltage drops. In symbols, $E_t - V_t$.

(circuit)

79. Kirchhoff's Circuit Law applies only if the conditions of a circuit are fulfilled; that is, there must be 1) a ______ for electron flow, and 2) a ______.

(complete path; source of EMF)

80. In applying ______ Law, the total sum of the EMFs depends on the polarity of the battery connections. The voltage drops, however, always add together in finding their sum.

(Kirchhoff's Circuit)

81. (See diagram No. 81) The diagram shows a circuit consisting of three elements, A, B and C. Kirchhoff's Circuit Law for this is: Current through B is from ______ to ______. E_a + ______ = I_b x ______.

(E_c, R_b; top, bottom)

82. Kirchhoff's Circuit Law is not affected by interchanging the order of the elements in the circuit. The equation may be different, however, if the polarity of the sum of the ______ if reversed. (batteries)

83. A systematic approach to using Kirchhoff's Circuit Law is the following: start at any point in the circuit and trace around it. First sum all the ______ according to polarity, (add or subtract). Then, retrace adding all ______ drops (IxR drops). Then, $E_t = V_t$ (EMFs voltage)

84. (See diagram No. 84) If we trace the circuit from point X in the direction shown, $E_t = E_a + (\ \ ) - (\ \ )$. $V_t = I_b \times R_b + I_c \times (\ \ ) + (\ \ ) \times (\ \ )$. ($E_d = E_f$... $+ I_c \times R_c + I \times R_e$

85. (See diagram No. 85) If resistances are connected in ________ the current through each of them is the same. If in the circuit, $I_a - 3.4$ amps, $I_b =$ __________ and $I_c =$ ________. (series $I_b = I_c = 3.4$ amps)

86. (See diagram No. 86) In a series circuit the ________ has the same value everywhere in the circuit. Therefor, in calculating voltage drops it is nenecessary to identify each individual current. (___________) $= IR_e + IR_b + IR_a$ (current $E_d - E_c$)

87. (See diagram No. 87) Kirchhoff's Circuit Law for the diagram is: $10 + (\underline{\hspace{1.5em}}) - 2\,I + 3.5\,I + 4.5\,I$. To find the current, $I - \frac{\underline{\hspace{3em}}}{2+3.5+4.5}$ (4 volts $I = 1.4$ amps)

88. (See diagram No. 88) If in summing up the EMFs the total is a minus quantity, it means the actual direction of current is opposite to that assumed in tracing through the circuit. In the circuit, $I =$ _______. (2 amps)

89. (See diagram No. 89) In the circuit shown, $R_a = 4.5$ ohms and $R_c - 105$ ohms. I is known to be 1/3 ampere. $E_d =$ _________. If the direction of current is opposite to that shown, the $E_d =$ _________. ($E_d = 150$ volts $E_d = 50$ volts)

90. A portable radio is powered by two 45 volt batteries connected in additive series. 3 amperes flows through the 5 radio tubes which are in series. If all tubes are alike, the resistance of one tube is _________. (6 ohms)

91. In a _______ circuit only one current path exists, and the ______ amount of current flows through each element in the circuit. (series same)

92. Batteries and resistances can be connected up so that more than one ______ path exists. Such multiple circuit arrangements are called networks. (current)

93. If the arrangement is such that there is one and only one circuit, it is called a ______ circuit. If there are at least two circuits or closed paths, it is a ______.	(series network)
94. The two requirements of an electrical circuit are 1) a complete path ______ and 2) a ______. These are the criteria in determining the number of circuits in a network.	(for flow of electrons (or for current flow); source of EMF)
95. (See diagram No. 95) The diagram indicates that it is possible to "trace" 3 distinct complete paths for current flow. Of these 3 closed paths, or loops, number ____ is not a circuit because it contains no source of EMF. We therefore have a network of 2 circuits.	(No. three)
96. (See diagram No. 96) We determine the no. of circuits in a network by tracing every possible closed continuous path or loop and by checking to see that it includes a ______. The diagram shown contains ______ circuits.	(source of EMF no circuits)
97. (See diagram No. 97) In the diagram it is possible to trace 3 different loops. Of these each one contains a source of EMF. This is therefore a network of ______ circuits.	(th[illegible])
98. (See diagram No. 98) In the diagram there are ______ loops. Checking each loop for a source of EMF., we find there are _____ circuits in this network.	(6, 3)
99. In analyzing a circuit or network, we have two "tools" available: (1) $V_a = (\ ) \times (\ )$, which is a statement of Ohm's Law and 2) $E_t = (\ )$, which is a statement of Kirchhoff's Circuit Law.	($V_a = I_a \times R_a$ $E_t = V_t$
100. __________ Law applies to an individual resistance in a circuit. ________ Law applies to an individual circuit in a network.	Ohm's Kirchhoff's Circuit)
101. (See diagram 101) The network shown contains 2 circuits. Writing Kirchhoff's Law for circuit #1 - $E_c = I_b \times R_b$. The equation for circuit #2 is $(\ ) = (\ ) \times (\ )$.	($E_c = I_a \times R_a$
102. (See diagram No. 102) In the two circuit network shown, we wish to find I_c. We therefore consider circuit No. ____. Writing Kirchhoff's Law, (____) + (__) = I_c x (__).	(No. 2 $E_a + E_b = I_c \times R_c$)

103. (See diagram No. 103) The diagram shows the lighting system in an automobile. L is the left headlight and R is the right. $I_R = \frac{2+2+2}{5} =$ ____. $I_L =$ ______ $=$ ____.

($I_R =$ 12 amps
$I_L =$ 15 amps)

104. (See diagram No. 104) The network contains 3 circuits. The voltage drop across D (symbolyzed by V_d), is 8 volts. $V_b =$ ______. If $R_b = 3$ ohms, $I_b =$ ______.

(32 volts
10 2/3 amps)

105. (See diagram No. 105) In a network, there are always points at which the current devides and recombines. Such points are called Junction points. In the diagram, point X & Y are _____ points.

(Junction)

106. At a junction point in a network, the ______ devides. Hence, if a junction point exists between 2 resistances, the resistances are NOT connected in ______.

(current series)

107. (See diagram No. 107) In the network shown, points Z and ____ are junction points. The resistances ___, ___ and ___ are connected in series. Also current through A and ___ are equal.

(W; D, E, & F
A & B)

108. Another useful aid in solving complicated networks is the Junction Law. This Law states that total current arriving equals the total _____ leaving. In symbols, $I_{in} = I_{out}$.

(current)

109. (See diagram No. 109) At junction point X, $I_{out} = 5 + 7 = 12$ amperes. Using the Junction Law, $I_{in} = I_c =$ ____ amperes. At point Y, $I_{out} =$ ____ amperes.

(12 amperes
12 amperes)

110. (See diagram No. 110) At the junction point Z, $I_c = 3$ amps and $I_b - 7$ amps. $I_e =$ ___ amps directed ___ the junction point. I_d is 3 amps also, because C and D are connected in ______.

($I_e = 4$ amps
towards; series

111. We solve ANY network problem by using our three basic laws which are: $E_t = V_t$ (Kirchhoff's ______ Law); $I_{in} - I_{out}$ (______ Law); $E_a - I_a \times R_a$ (_______ Law).

(Circuit Junction,
Ohm's)

112. The procedure in solving a network for some unknown consists of 2 parts: First - Set up all the equations pertaining to the network; Second - Solve these ____ arithmetically for the required unknown.

(equations)

113. In setting up the equations for a network we follow these steps: a) Determine the number of circuits in the network. b) Write the Kirchhoff equation for each ____. c) Write the Junction Equation for ONE Junction point.

(circuit)

114. In solving a network of 3 circuits, four equations are needed as follows: one ____ equation for each of the three circuits, one ______ equation for any one junction point.

(Kirchhoff Junction)

115. In writing the equations for solving a network the total number of ____ is always one greater than the number of ____.

(equations circuit)

116. (See diagram No. 116) Set up the equations for the network shown: a) No. of circuits equals __________. b) Kirchhoff equation 1): 80 = I_a x 20. Kirchhoff equation 20 - 80 = I_b x (____). c) Junction equation X) - I_t = ____ + ___.

(two ;80 = I_b x 20;
$I_t = I_a + I_b$

117. (See diagram No. 117) Set up the equations for the network shown: a) No. of circuits = _____. b) Kirchhoff equation 1): ___ + ___ - I_c x 25. 2): 80 = I_d x R_d c) Junction equation is = 9 = I_c + _____.

(two ;
50 + 30; $I_c + I_d$)

118. Some of the circuits in a network may contain resistances in series. In this case we know that the _____ through each resistance is the same. This fact is useful in simplifying network equations.

(current)

119. (See diagram No. 119) Write the equation for the 2 circuits in the network in their simplest form: a) Kirchhoff equation 1) 6 = I_a x 3. Kirchhoff equation 2) 6 = I_c (___ + ___).b) ______ equation = I_t = ____ + ____.

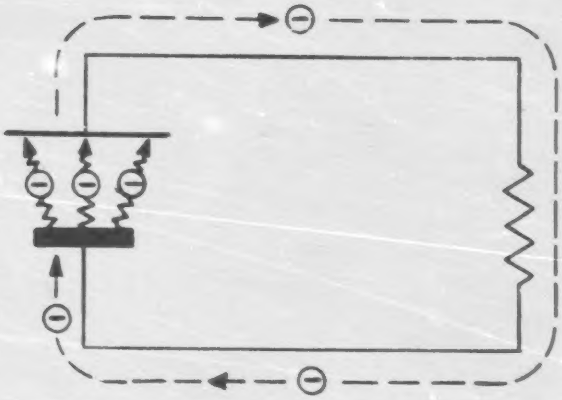
(6 - I_c (1 + 7)
Junction; $I_t = I_a + I_c$

120. (See diagram No. 120) The network shown consists of _____ circuits V_a = volts. Resistances_____ and _______ are in series. The Kirchhoff equation 1) in its simplest form is ____ = I_d x ____.

(3 circuits
V_a = 6 volts
R = I_d x 5.5)

Diagrams For Advanced Programming

DIAGRAM NO. 64



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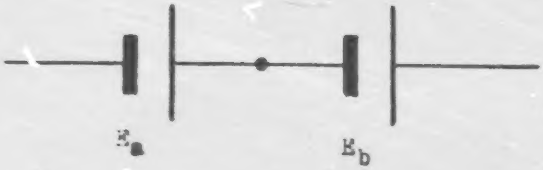

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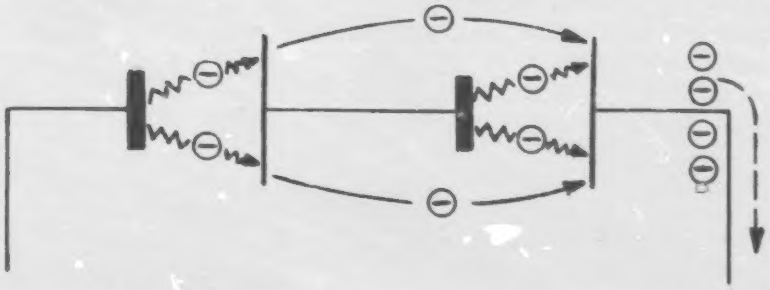

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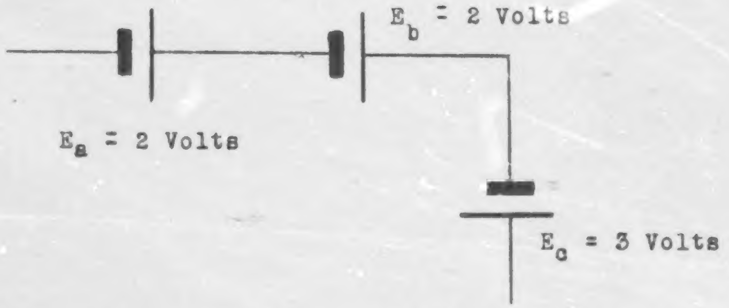

E_b = 2 Volts
E_a = 2 Volts
E_c = 3 Volts

DIAGRAM NO. 71

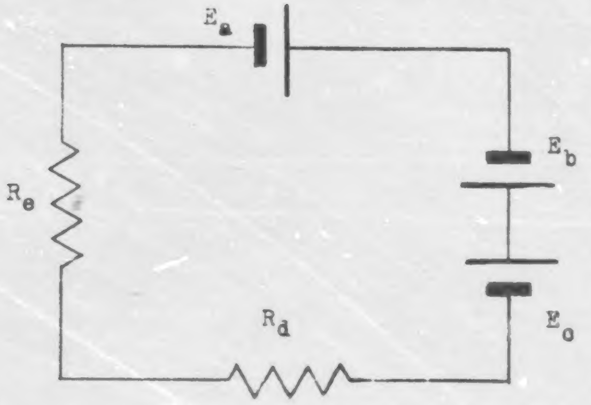

E_a
E_b
R_e
E_c
R_d

DIAGRAM NO. 72

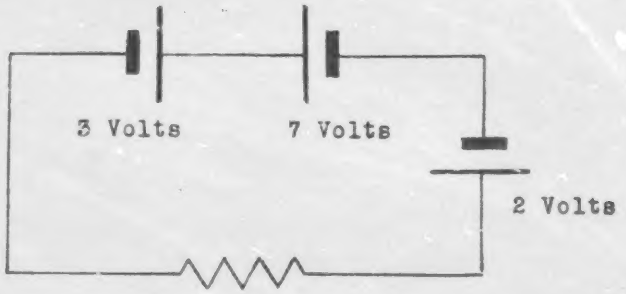

3 Volts
7 Volts
2 Volts

DIAGRAM NO. 73

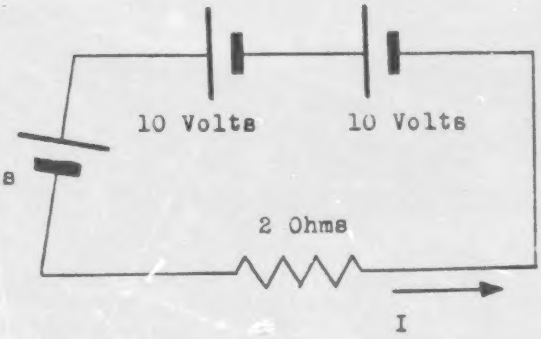

10 Volts
10 Volts
6 Volts
2 Ohms
I

DIAGRAM NO. 74

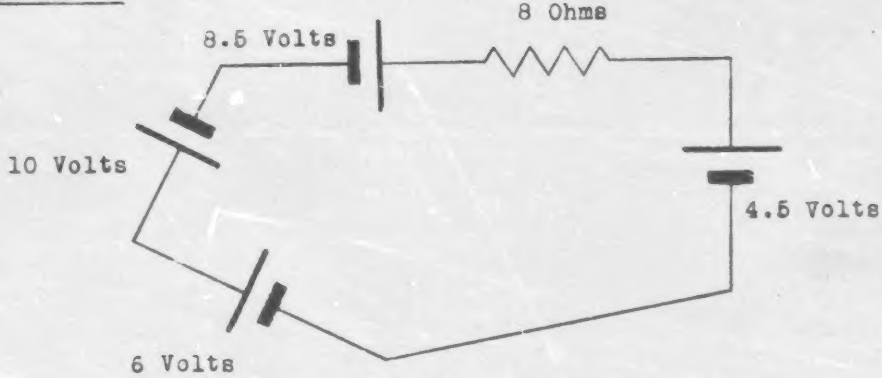
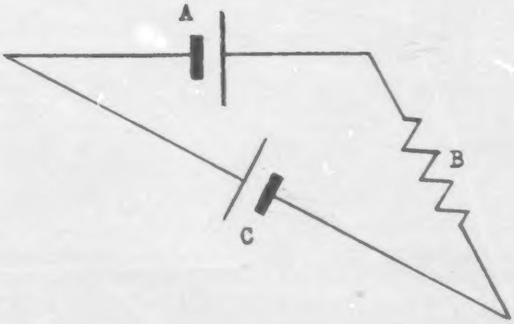

8 Ohms
8.5 Volts
10 Volts
4.5 Volts
6 Volts

DIAGRAM NO. 81



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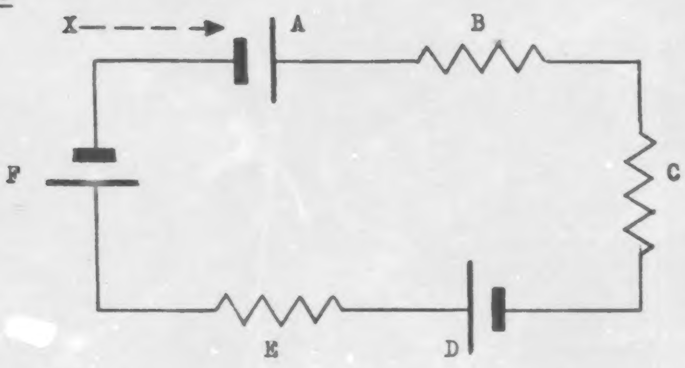

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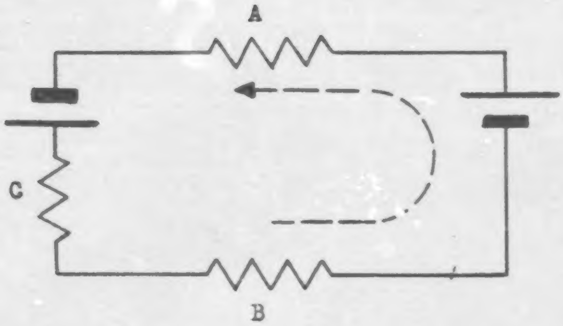

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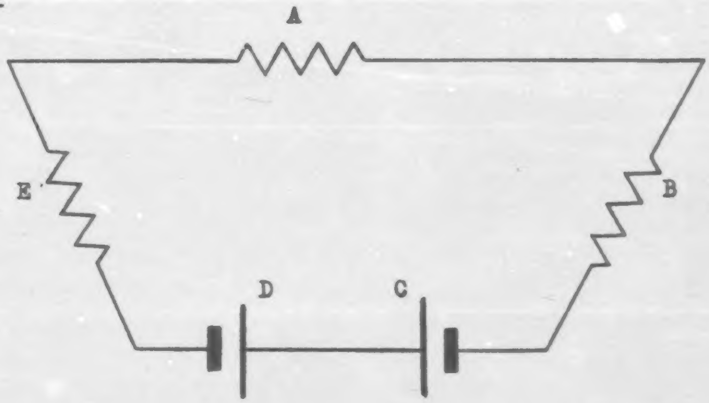

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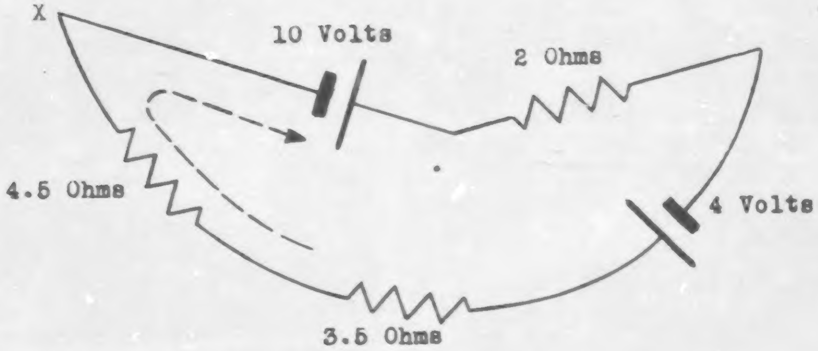

X
10 Volts
2 Ohms
4.5 Ohms
4 Volts
3.5 Ohms

DIAGRAM NO. 88

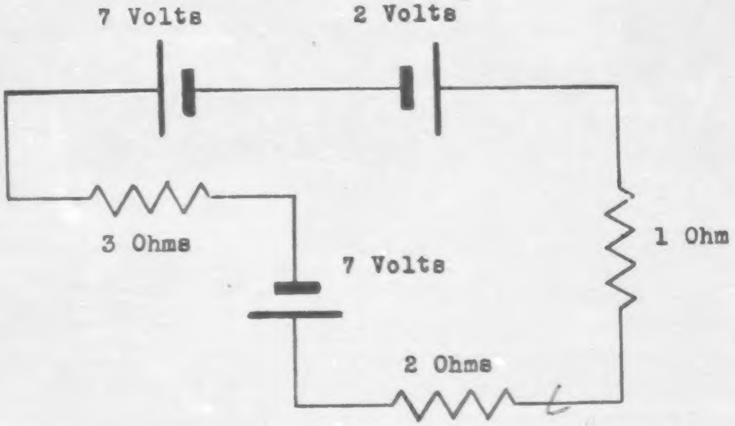

7 Volts
2 Volts
3 Ohms
7 Volts
1 Ohm
2 Ohms

DIAGRAM NO. 89

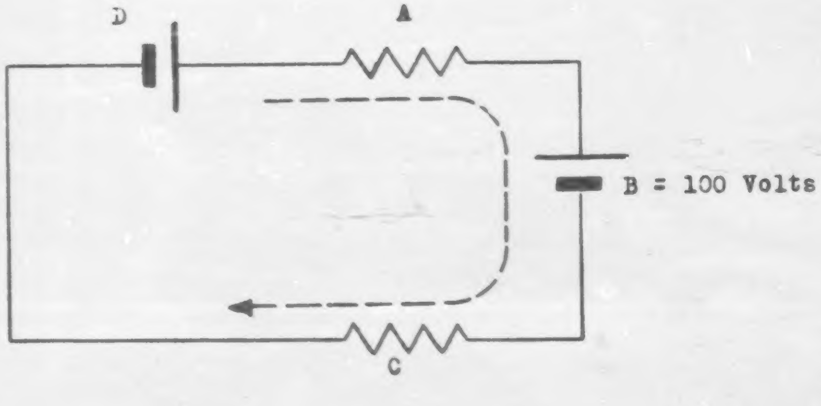
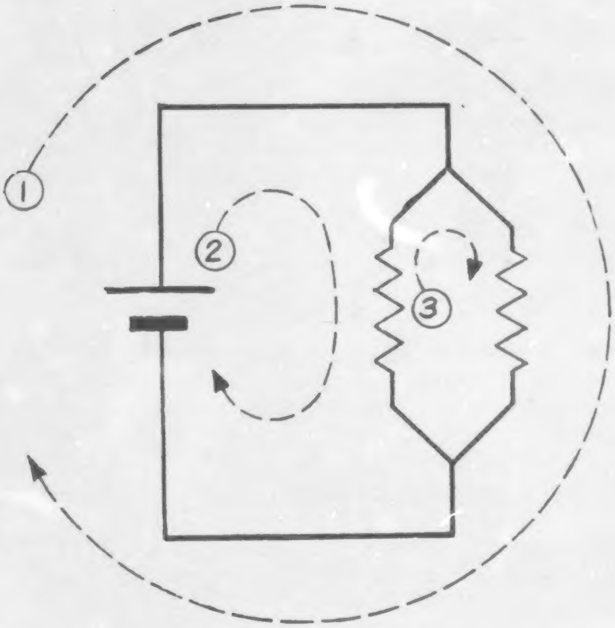

D
A
B = 100 Volts
C

DIAGRAM NO. 95



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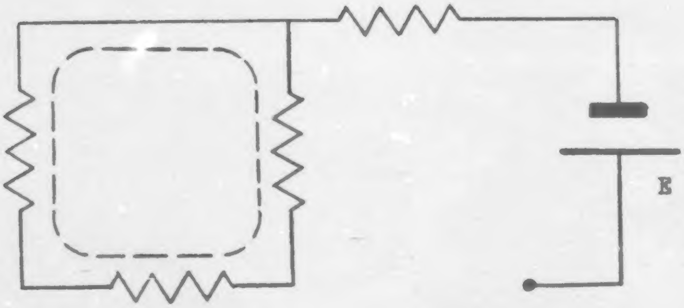

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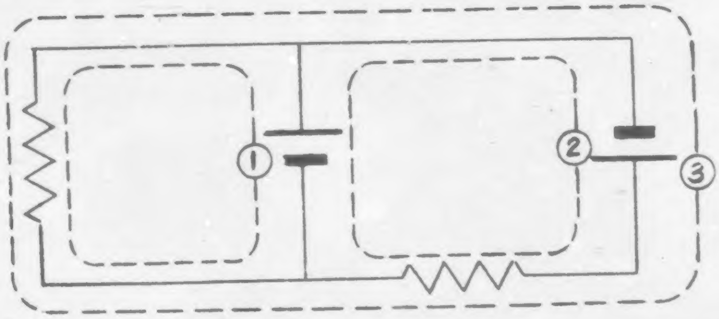

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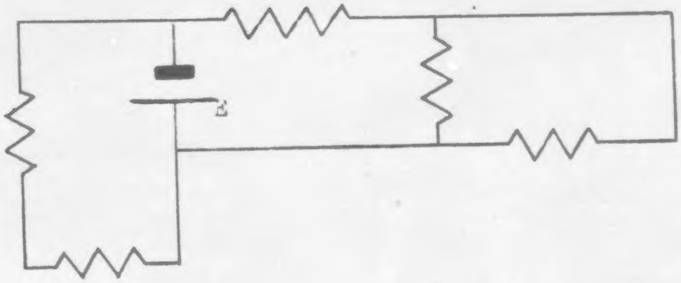

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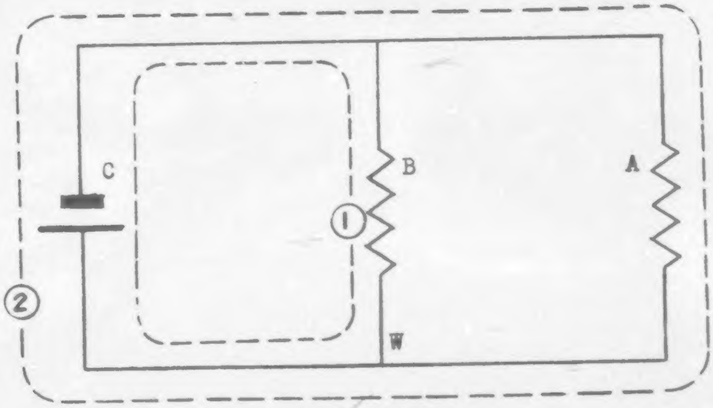

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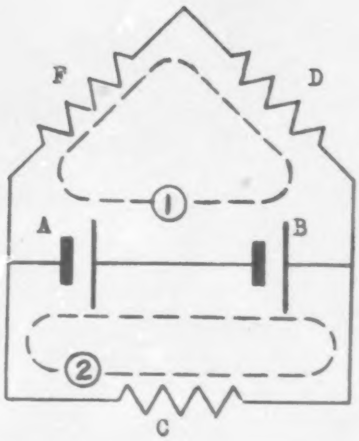

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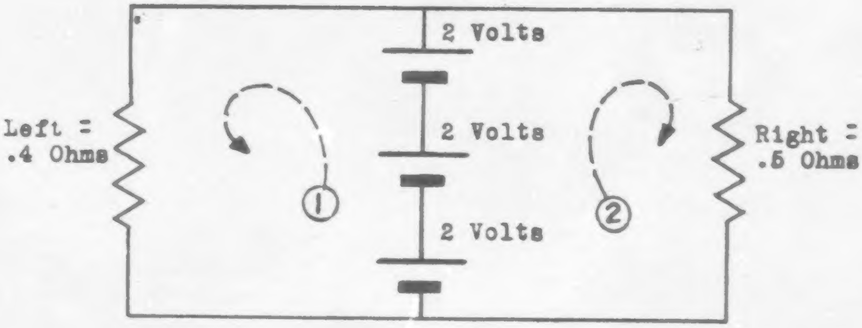

2 Volts
2 Volts
2 Volts
Left =
.4 Ohms
Right =
.5 Ohms
①
②

DIAGRAM NO. 104

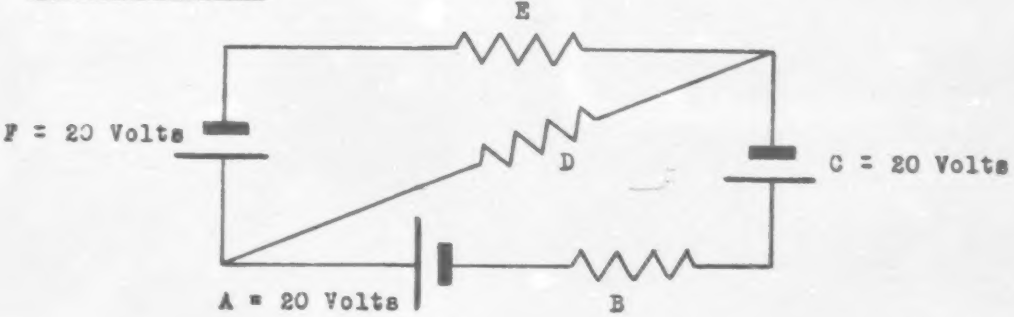
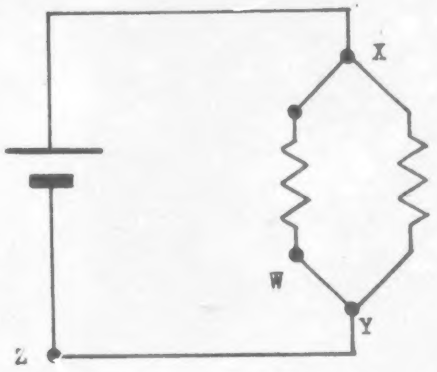

E
F = 20 Volts
D
C = 20 Volts
A = 20 Volts
B

DIAGRAM NO. 105



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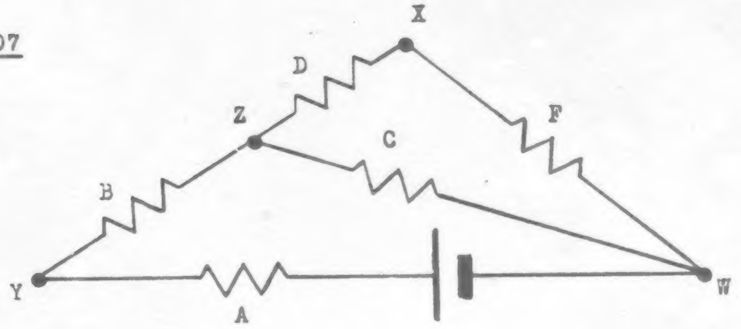

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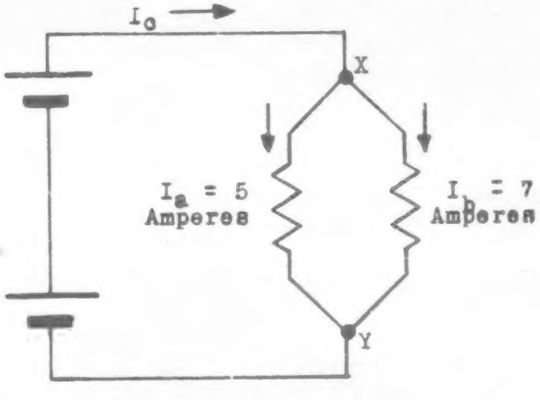
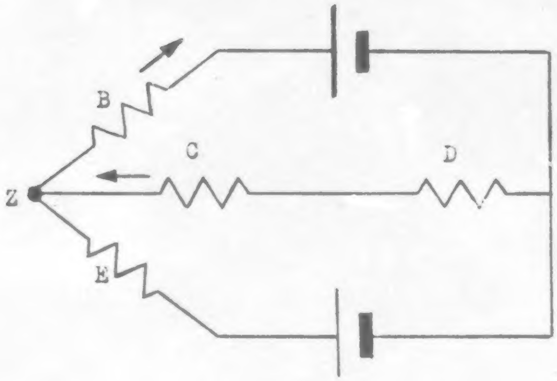

I_o
X
I_a = 5 Amperes
I_b = 7 Amperes
Y

DIAGRAM NO. 110



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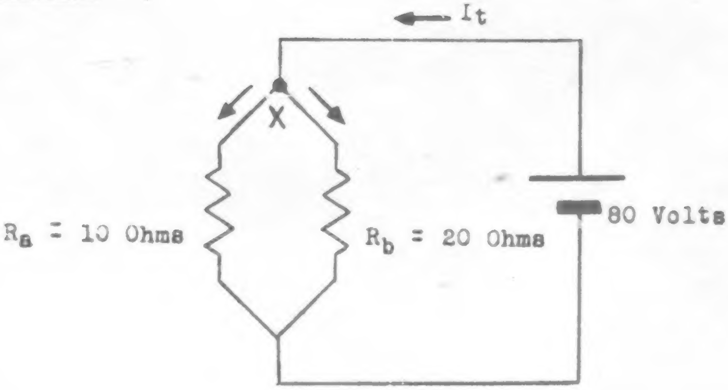

I_t
X
R_a = 10 Ohms
R_b = 20 Ohms
80 Volts

DIAGRAM NO. 117

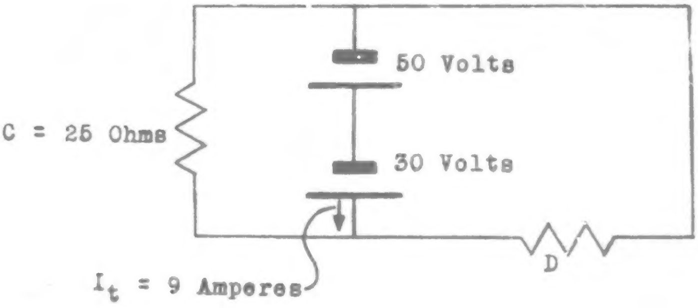

50 Volts
C = 25 Ohms
30 Volts
I_t = 9 Amperes
D

DIAGRAM NO. 119

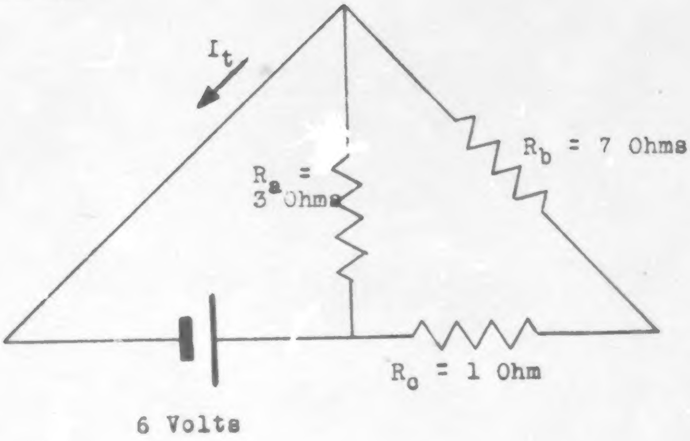
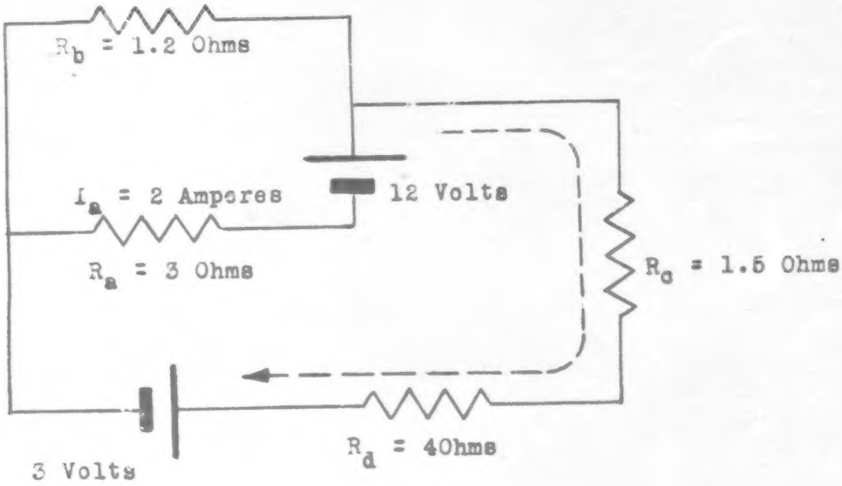

I_t
R_a =
3 Ohms
R_b = 7 Ohms
R_c = 1 Ohm
6 Volts

DIAGRAM NO. 120


R_b = 1.2 Ohms
I_a = 2 Amperes
12 Volts
R_a = 3 Ohms
R_c = 1.5 Ohms
R_d = 4Ohms
3 Volts

APPENDIX H

Completion Items Re-Programmed for the Skinner Teaching Machine

1. All effects of electricity can be explained by the movement of free____.	(electrons)
2. Electrons will move if two conditions are fulfilled: a) an excess of electrons in one place and a lack in another; and b) a____between the two.	(complete path)
3. In order to build up an excess of electrons in one place and a lack in another, some kind of energy or force is required. This force is called____force.	(electromotive)
4. One source of electromotive force for maintaining an unbalance of electron accumulation is a battery. A battery employs chemical action to create an____.	(electromotive force)
5. An electrical cct. exists whenever we have a source of electromotive force (abbr. EMF) and a____path for the flow of electrons.	(complete)
6. The presence of both a source of EMF and a complete path for electrons defines an electrical____.	(circuit)
7. (See diagram No. 7) In the symbol for a battery the long line represents the excess of electrons and the short line, the____of electrons.	(lack)
8. (See diagram No. 8) In an attempt to get from the excess to the lack side of the battery the electrons must flow through the wire (or circuit) because a battery transfers electrons in only one____.	(direction)
9. (See diagram No. 9) By internal chemical action, a battery continually transfers electrons from the lack to the excess side (or terminal). Thus, a____in the accumulation of electrons is maintained.	(difference)
10. (See diagram No. 10) Inside a battery, chemical action transfers electrons from____to____terminal. In the cct. however, electrons move from excess to lack terminal.	(lack to excess)
11. When a battery transfers electrons internally it is creating the____force necessary to make current flow in a cct.	(electromotive)

circuit

battery

Battery

12. (See diagram No. 12) If electrons are permitted to build up at the lack terminal, eventually the number of electrons at both terminals will balance. With this condition, ____ will flow. (no current, no electrons)

13. The EMF of a battery is a measure of how rapidly electrons are being transferred internally. The ____ the transfer, the higher the EMF. (faster)

[illegible]

14. The rate at which electrons flow past a given point in a cct. is called current. Current is measured in ____. (amperes)

15. (See diagram No. 15) Since a battery maintains a continuous unbalance of electrons between its terminals, the current in the cct. always ____ the current through the b attery. (equals)

16. (See diagram no. 16) The direction of current flow in a cct. depends on which way the battery terminals are facing. In the diagram, current passes through resistance A from point ____ to point ____. (pt. Y to X)

17. (See diagram No. 17) The diagram represents an electrical cct. because it contains a) a source of ____ and b) complete ____. (EMF; path for electrons)

[illegible]

18. In driving a nail into a piece of wood, a certain force must be expended due to the resistance of the ____. (wood)

19. In operating a flashlight, electromotive force is expended due to the resistance of the bulb. This EMF is supplied by the flashlight ____. (battery)

20. In forcing a current thru a ____, electrical force is expended. This force is called voltage drop (abbr. V) (resistance)

expended

21. If more current passes thru a resistance, the voltage drop is ____. (higher; greater)

22. If the resistance thru which a current flows is decreased, the ____ is reduced. (voltage drop)

23. For every resistance in cct. there is an interdependence between voltage drop, resistance and ____. This mathematical relationship is called Ohm's Law. (current)

expand

state opposite
+ refer back to V.D.

24. _____ states that voltage drop (V) is directly proportional to both current (I) and resistance (R) through which it flows. (Ohm's Law)

25. In symbols, Ohm's Law is written $V = IR$ where V is expressed in volts, I in _____, and R in ohms. (amperes)

26. According to Ohm's Law a voltage drop of _____ volts results if 2 amperes are forced through a resistance of 3 ohms. (six)

27. (See diagram No. 27) In the circuit shown, the current through resistance A is 4 amps. The V_a is 12 volts. T Therefore A has a resistance of _____ ohms. (three)

28. If the current through a resistance is doubled while the resistance is halved, V is _____. (unchanged)

29. Ohm's Law is valid only if all quantities are expressed in their proper units. Thus 8 _____ = 32 _____/4 ohms. (amps; volts)

30. (See diagram No. 30) In the diagram shown, V_b is 40 volts. Current through B is _____. (5 amps)

31. If there are both a source of EMF and a complete path for flow of electrons, an electrical _____ exists. (circuit)

32. The function of an EMF is to maintain a continuous _____ in the number of free electrons between 2 points in the circuit. In a _____ these two points are the excess and the lack terminals. (difference; battery)

33. (See diagram No. 33) If there is no complete path for electron flow, the electrons will build up at the break in the path until the unbalance is destroyed. Hence electron flow will cease and no _____ exists. (electrical circuit)

34. (See diagram No. 34) In an electrical circuit no electron build-up occurs anywhere. Therefore, rate of electron flow (or _____) through both the external path and the battery itself must be _____. (current; equal)

35. (See diagram No. 35) A circuit can include more than one resistance. If the resistances are connected end to end in chain fashion it is called a series connection. The diagram shows _____ resistances connected in series. (three)

36. The distinctive feature of a series connection is that all current flowing through one resistance must necessarily flow through the second _____. (resistance)

37. If, in any circuit, two resistances are connected so that all the current leaving one enters the second resistance, these are _____ connected. (series)

Series cont'd

38. (See diagram No. 38) Of the 4 resistances shown, resistances _____ and _____ are the only two which must have the same current flowing through them. Resistances _____ and _____ however, are not series connected with any other resistance. (C, D; A, B)

39. (See diagram No. 39) Current in circuits flows through batteries as well as through resistances; therefore, batteries, like resistance can also be connected in _____. (series)

40. A series circuit is one in which all elements (batteries and resistances) are connected so that the _____ through all elements is the same. (current)

41. (See diagram No. 41) In the series circuit shown, current through R_a is 4 amps. I_b - _____ amps. Current through battery is _____. (4 amps; 4 amps)

42. (See diagram No. 42) Voltage drop through resistance B is 10 volts. I_b = _____. I_a = I_b because the resistances are in series. V_a - _____. (5 amps; 15 volts)

43. In any series circuit three conditions exist: 1) _____ for current 2) source of _____ 3) current in all elements is _____. (complete path; EMF; equal)

44. Electrical circuits, in common with many phenemena of the physical world, obey a fundamental law of nature: the force taken out of a system must equal the force _____ the system. (put into)

Kirchhoff's Law

45. In driving a nail, the force necessary to overcome the _____ of the wood is provided by the force of the carpenter's hammer. (resistance)

46. In an electrical circuit the force needed to push current through a resistance (voltage drop) is provided by the _____ of a battery. (EMF)

47. In any electrical circuit the sum of all the _____ must exactly equal the sum of all the EMFs. This is known as Kirchhoff's Law. (voltage drops)

48. Kirchhoff's Law can be expressed mathematically thus: In any _____ E total = V total. circuit

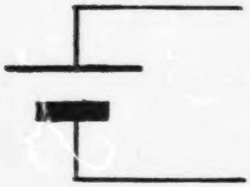
49. Kirchhoff's Law is applicable only if the definition of electrical circuit is met: a) source of _____; and b) complete path for _____. (EMF; electron flow or current)

O.L.
K.L

50.	_____ Law ($V = IR$) applies only to a _____. _____ Law ($E_t = V_t$) applies only to an electrical circuit.	(Ohm's Law; resistance; Kirchhoff's Law)
51.	(See diagram No. 51) By applying Kirchhoff's Law, we know that V_a = _____.	(four volts)
52.	(See diagram No. 52) I_b = 50 amperes. The voltage drop across A is _____. Since this is a series circuit, current through all resistances is _____.	(100 volts; equal)
53.	(See diagram No. 53) V_a is 8 volts. By using Ohm's Law and Kirchhoff's Law we can calculate resistance of C to be _____ ohms.	(3/4 ohms)
54.	(See diagram No. 54) In a battery, the surplus of electrons (or EMF) always appears at the _____ terminal. Hence the _____ of current flow in a circuit depends on which way the battery is connected.	(excess; direction)
55.	(See diagram No. 55) Batteries, like resistances, can also be connected in series. Each individual battery serves to speed up electron flow as current passes through it. Thus each battery contributes its own _____ to the total in the circuit.	(EMF)
56.	(See diagram No. 56) If two batteries in series are connected in opposition, one speeds up electrons while the other _____. Hence, total EMF is the _____ of the individual EMFs.	(slows them down; difference)
57.	(See diagram No. 57) All batteries are connected to aid one another. E_t = _____/ From Kirchhoff's Law, V_a = _____.	(22 volts; 22 volts)
58.	(See diagram No. 58) Two batteries are in opposition, therefore total EMF in the circuit is _____. Direction of current flow is from resistance _____ to _____.	(E_t = 4 volts; B to A)
59.	(See diagram No. 59) _____ Law applies to an electrical circuit regardless of the number and placement of resistances and batteries. In the circuit show, V_t = _____.	(Kirchhoff's; 105 volts)
60.	(See diagram No. 60) The current through C is 10 amperes. V_c is _____. EMF of battery X is _____.	(5 volts; 65 volts)

expand

DIAGRAM NO. 7



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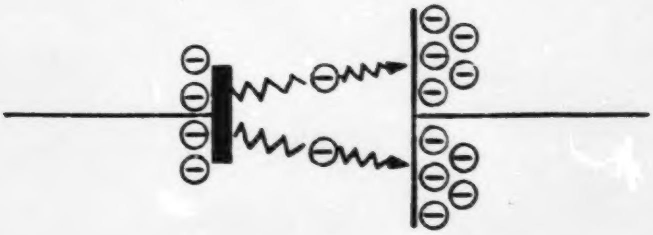

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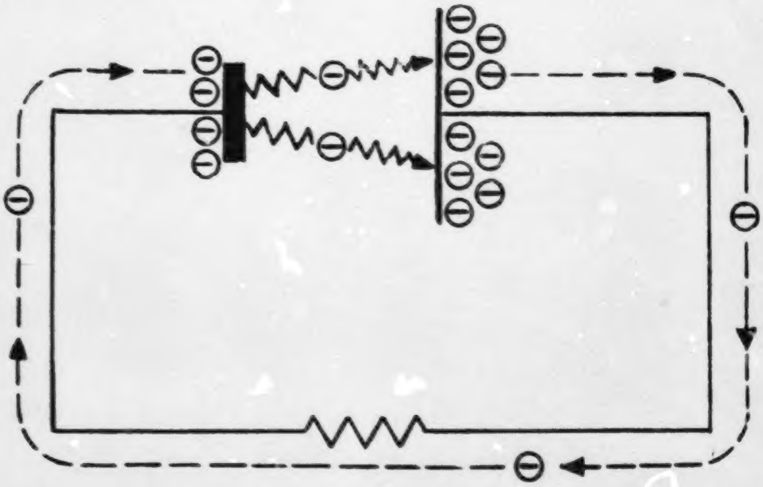

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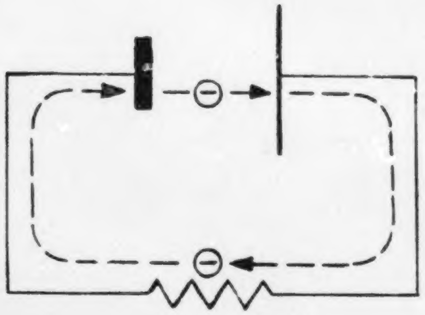


DIAGRAM NO. 12

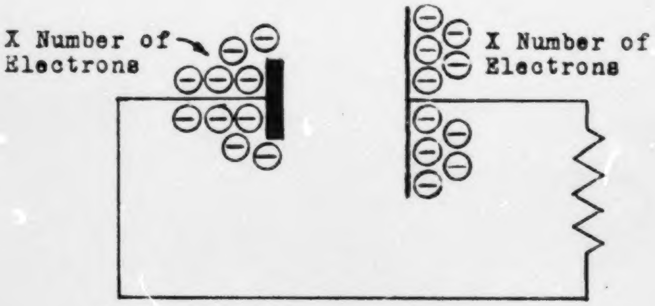

X Number of
Electrons
X Number of
Electrons

DIAGRAM NO. 15 & NO. 34

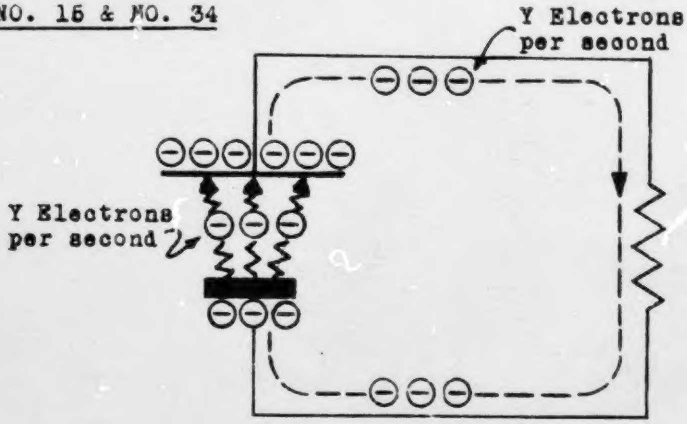

Y Electrons
per second
Y Electrons
per second

DIAGRAM NO. 16, NO. 17, and NO. 27

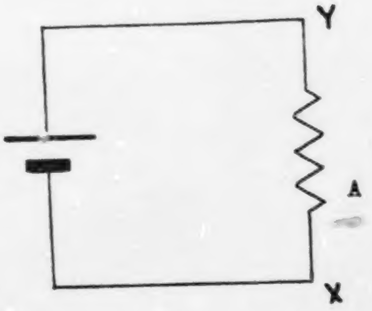


DIAGRAM NO. 30

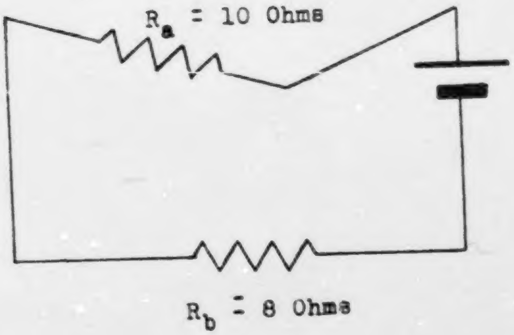

R_a = 10 Ohms
R_b = 8 Ohms

DIAGRAM NO. 33

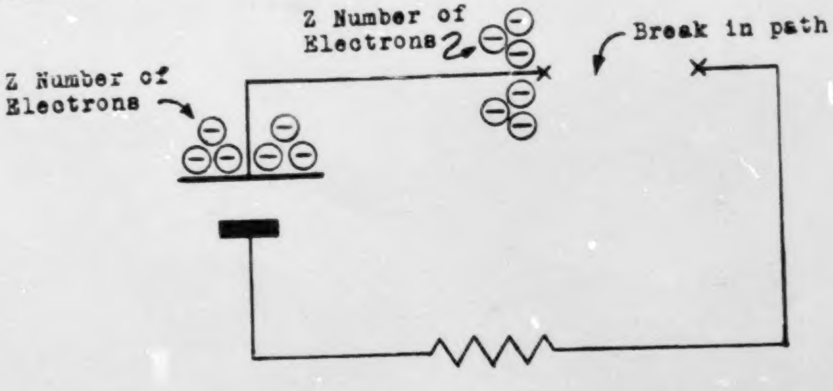
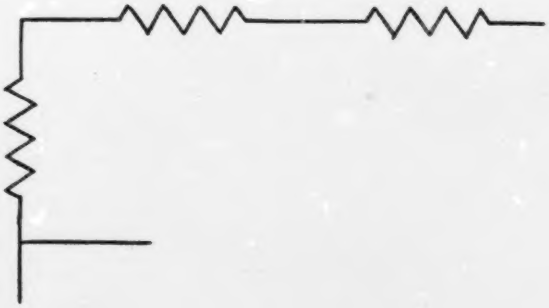

Z Number of Electrons
Z Number of Electrons
Break in path

DIAGRAM NO. 35



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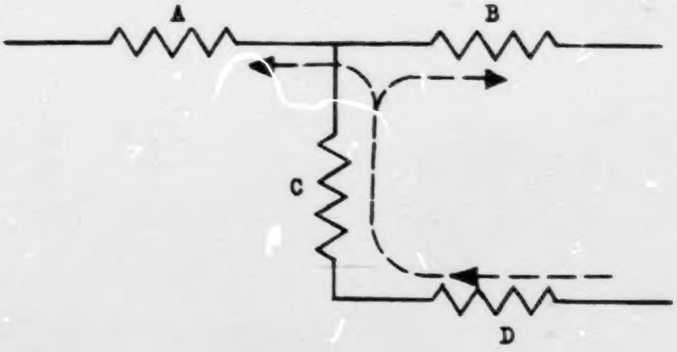

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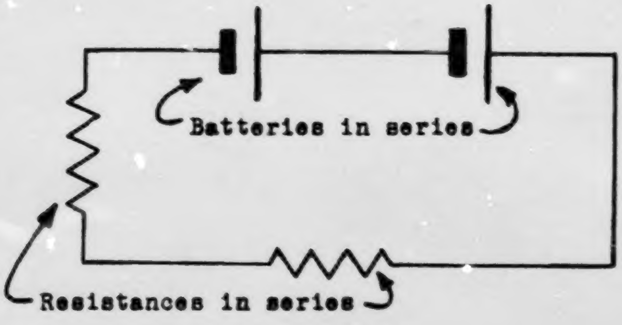

Batteries in series
Resistances in series

DIAGRAM NO. 41

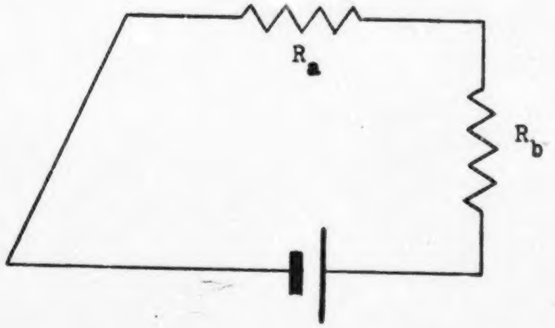


DIAGRAM NO. 42

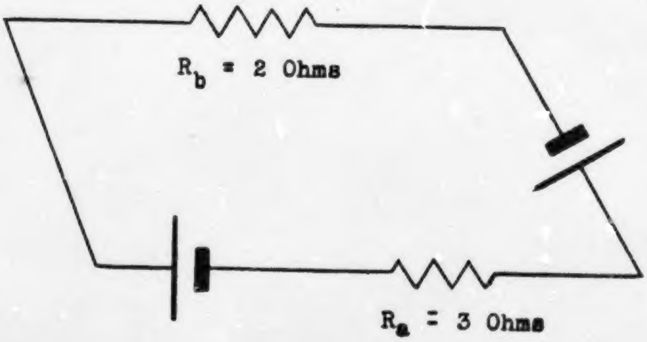

R_b = 2 Ohms
R_a = 3 Ohms

DIAGRAM NO. 51

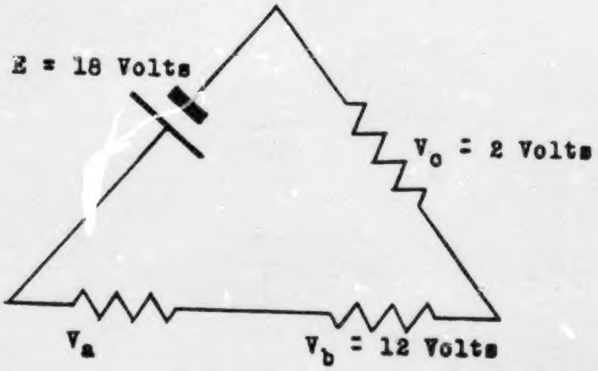

E = 18 Volts
V_c = 2 Volts
V_a
V_b = 12 Volts

DIAGRAM NO. 52

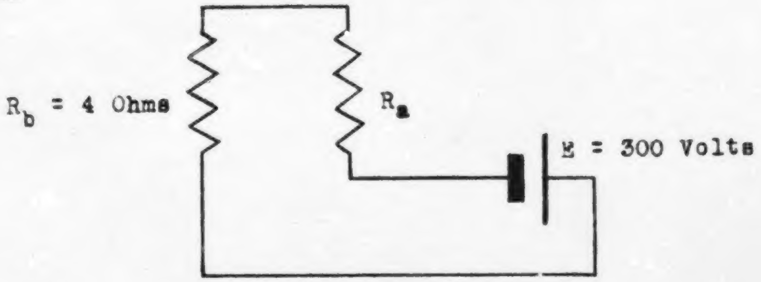

R_b = 4 Ohms
R_a
E = 300 Volts

DIAGRAM NO. 53

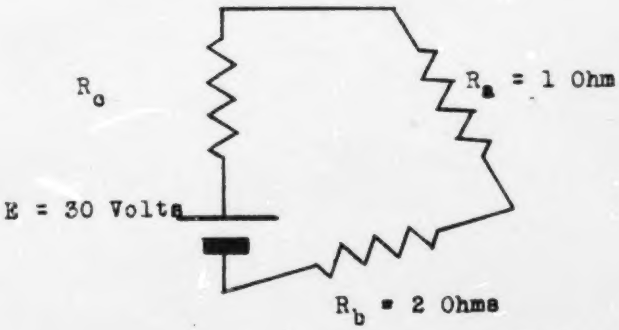
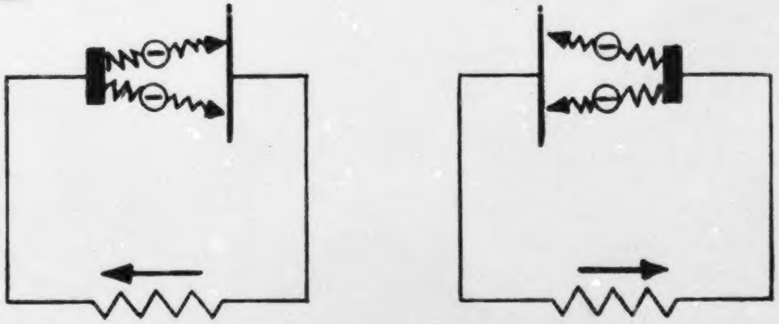

R_c
R_a = 1 Ohm
E = 30 Volts
R_b = 2 Ohms

DIAGRAM NO. 54



Arrangement No. 1

Arrangement No. 2

DIAGRAM NO. 55

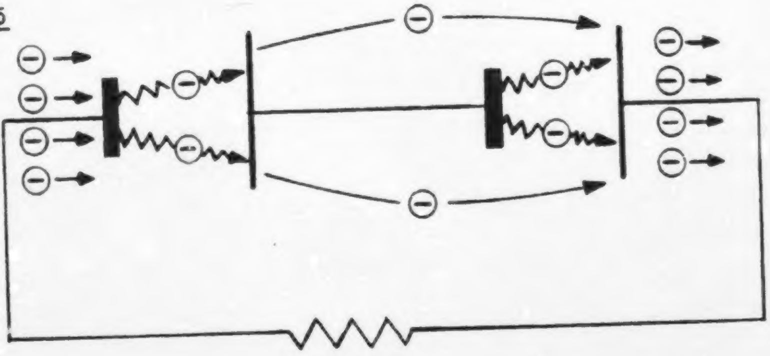


DIAGRAM NO. 56

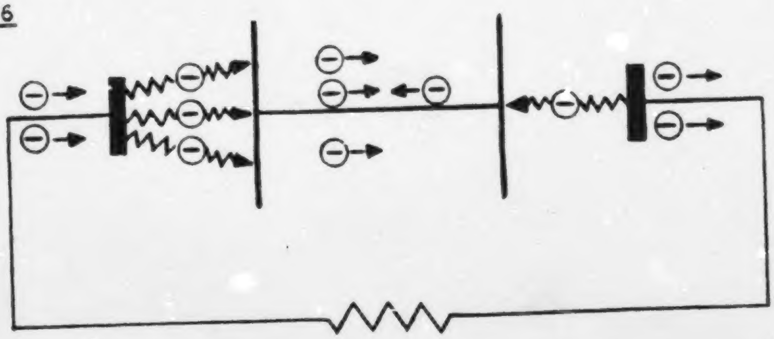


DIAGRAM NO. 57

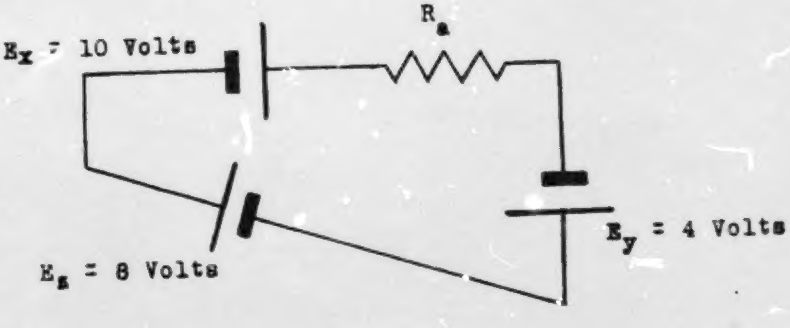

E_x = 10 Volts
R_a
E_y = 4 Volts
E_z = 8 Volts

DIAGRAM NO. 58

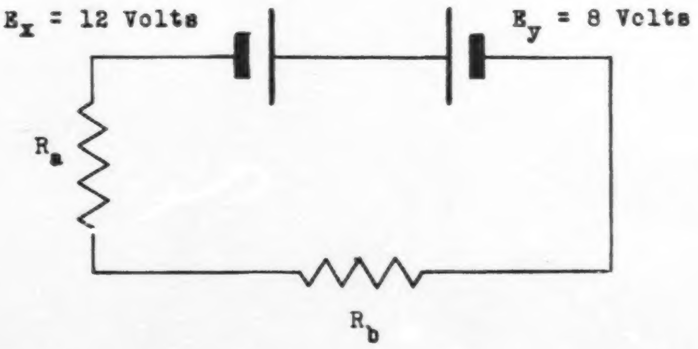

E_x = 12 Volts
E_y = 8 Volts
R_a
R_b

DIAGRAM NO. 59

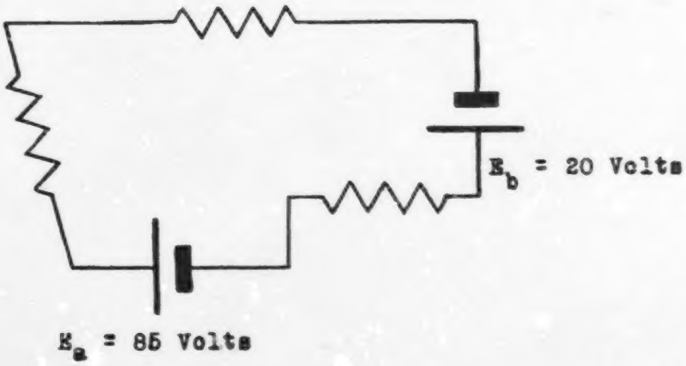
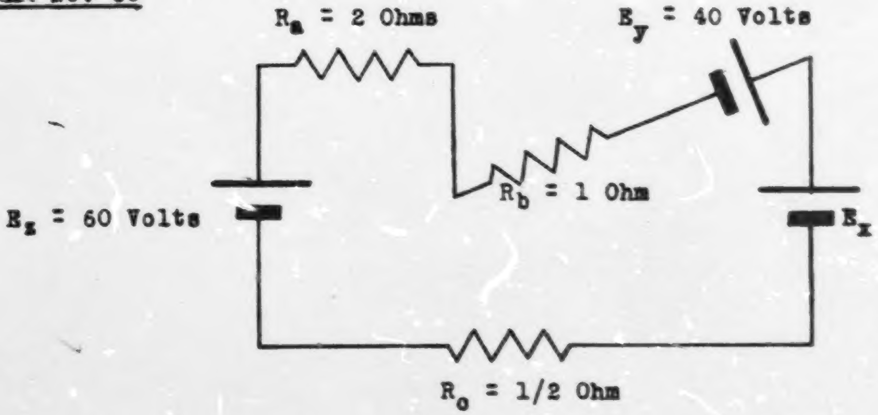

E_b = 20 Volts
E_a = 85 Volts

DIAGRAM NO. 60


R_a = 2 Ohms
E_y = 40 Volts
R_b = 1 Ohm
E_z = 60 Volts
E_x
R_o = 1/2 Ohm

APPENDIX H

Preliminary Completion Items

"What Electricity Is"

1. The effects of electricity can be explained and predicted by assuming the existence of a tiny particle called the _____. (electron)

2. Electricity is the movement of _____ from place to place. (electrons)

3. Electricity depends on the excess or lack of _____ in a material. (electrons)

4. The movement of electrons is the cause of all _____ and effects. (electrical; electronic)

5. The electron is one part of the _____. (atom)

6. The electron is _____ than the atom. (smaller)

7. The electron is a part of the _____. (atom)

8. The atom is smaller than the _____. (molecule)

9. The atom is a part of the _____. (molecule)

10. The electron is therefore a part of the _____ which in turn makes up the _____. (atom; molecule)

11. The molecule is the combination of two or more _____. (atoms)

12. All materials are made up of different combinations of _____ to form _____ of the material or matter. (atoms; molecules)

13. The hydrogen atom, greatly magnified, looks like a "sun" with a "planet" spinning around it. The planet is known as an _____. (electron)

14. The "sun" is known as the _____. (nucleus)

15. The hydrogen atom, therefore, consists of _____ and _____. (one electron; a nucleus)

16. The electron or electrons of any atom are _____ charged. (negatively)

17. The nucleus of any atom is _____ charged. (positively)

18. The nucleus of any atom is made up of _____ and _____. (protons; neutrons)

19. Protons are the _____ charged parts of the nucleus. They therefore make the nucleus _____ charged. (positive; positively)

20. Neutrons, as the name implies, are the _____ part of the nucleus. (electrically neutral)

21. Each neutron, to be neutral, consists of one _____ and one _____ bonded together. (electron; proton)

22. Electrons circle the nucleus at different distances from the nucleus, that is, in different _____. (orbits)

23. Those in the outer orbits are called _____ electrons. (free)

24. The electrons that orbit closer to the nucleus are called _____ electrons. (bounded)

25. The total number of _____ charged electrons of any atom circling around the nucleus always exactly equals the number of _____ charged _____ in the nucleus. (negative; positive; protons)

26. All atoms are made up of _____ plus _____ plus _____. (neutrons; electrons; protons)

27. Free electrons are attracted by _____ force to the nucleus than the bound electrons. (less)

28. _____ electrons can be easily forced from their orbits while _____ electrons cannot. (free; bound)

29. There is no electricity unless _____ move, or there are _____ or _____ in a material. (electrons; too many; too few)

30. It is the movement of _____ electrons through a material that makes up an electrical current. (free)

APPENDIX H

Preliminary Completion Items

"Static Electricity"

1. When an _____ is forced out of its orbit then the _____ action would become what is known as electricity. (electron; electrons)

2. Electrons forced out of their orbits create a _____ electrons in the material they leave. (lack of)

3. Electrons gathering together create an _____ electrons in the material in which they come to rest. (excess of)

4. An excess of electrons in a material is called a _____ charge. (negative)

5. A lack of electrons in a material is called a _____ charge. (positive)

6. Electrons are negative. Therefore, their accumulation creates a _____ charge. (negative)

7. Electrons must move from one place to another to create either a _____ or a _____ charge. (negative; positive)

8. The positively charged protons _____ move. (do not)

9. The positively charged nuclei _____ move. (do not)

10. The neutrons _____ move. (do not)

11. When _____ and _____ charges exist you have what is called static electricity. (negative; positive)

12. In order to create static electricity only _____ move. (electrons)

13. A main source of static electricity is _____. (friction)

14. If two different materials are rubbed together the orbits of the ____ cross and they may transfer from one material to another. (electrons)

15. The material which gains electrons from friction would have a _____ charge. (negative)

16. ______ can be used to produce both positive and negative charges. (friction)

17. The material which loses electrons from friction would have a _____ charge. (positive)

18. _____ produces static electricity. (friction)

19. _____ will cause one material to give up electrons and the other to take on electrons. (friction)

20. A material which is neither positive nor negative charged has neither a _____ nor an _____ of electrons. (lack; excess)

21. Some materials such as glass, amber, hard rubber, waxes, flannel, silk, rayon and nylon easily build up static electricity through friction. That is, _____ flow from one to the other with ease. (free electrons)

22. Prior to friction, the materials contain an _____ number of electrons, negative charge, and _____ positive charge. (equal; protons)

23. When a glass rod is rubbed with silk, the rod loses electrons. The glass rod thereby becomes _____ charged and the silk becomes _____ charged. (negatively; positively)

24. When a rubber rod is rubbed with fur the fur loses electrons. Therefore, the rubber rod becomes _____ charged and the fur becomes _____ charged. (negatively; positively)

25. A negative or positive charge of static electricity can be produced by _____. (friction)

26. A negatively charged object or material is attracted to a _____ charged object or material. (positively)

27. A negatively charged object or material is replaced by a _____ charged object. (negatively)

28. Unlike charges _____. (attract)

29. Like charges _____. (repel)

30. Attraction takes place because the excess of _____ are trying to find a place where _____ are needed. (electrons; electrons)

31. While most static charges are due to _____ they may be produced by contact. (friction)

32. A _____ is the transfer of a charge from a charged material to another uncharged material by direct contact. (contact charge)

33. If a negatively charged rod is brought into contact with one end of an uncharged metal bar some _____ will flow from rod to bar. (electrons)

34. If a negatively charged rod is brought into contact with an uncharged metal bar the rod will become less _____ and the bar will become _____. (negatively charged; negatively charged)

35. If a positively charged rod is brought into contact with an uncharged metal bar some _____ will leave bar into rod and the bar will become _______ and the rod will become less _____.	(electrons; positively charged; positively charged)
36. A negative or positive charge of static electricity can be produced by _____ and by _____.	(friction; contact)
37. An _____ is the charge produced on an uncharged material from another charged material without actual contact.	(induction charge)
38. A negative charged rod brought near one end of an uncharged bar _____ electrons in the bar to the other end of the bar. The point nearest rod becomes _____ and the other end _____ charged.	(repels; positively negatively)
39. If, before a negatively charged rod is removed a path is provided for the electrons in the negatively charged portion of the bar to flow out, the bar will become_____.	(positively charged)
40. If a negatively charged rod is brought close to one end of an uncharged bar and a finger placed at the other end, then electrons will be _____ from rod and bar to finger and the bar will become _____ charged.	(repelled; positively)
41. A positively charged rod brought near one end of an uncharged metal bar _____ electrons toward that end of the bar.	(attracts)
42. If before a positively charged rod is removed, a path is provided for electrons to flow into the other end of the bar, then the bar will become _____.	(negatively charged)
43. If a positively charged rod is brought close to one end of an uncharged bar and a finger placed at the other end, then electrons will be _____ to rod into the bar from the finger and the bar will become______.	(attracted; negatively charged)
44. A material can be both _____ and _____ charged by friction, contact, and _____.	(negatively; positively; induction)
45. If you bring two materials of opposite charges together, the _____ of the negative charge will transfer to the material having a _____ or positive charge.	(excess of electrons; lack of electrons)
46. The transfer of electrons from a negatively charged material to a positively charged material is called a ______.	(transfer)

47.	A contact discharge is the crossing over of _____ from a negative charge to a positive charge through contact.	(electrons)
48.	An arc discharge is the crossing over of _____ from a negative charge to a positive charge through an arc and not through contact.	(electrons)
49.	A discharge cannot take place between _____ and _____ charged objects.	(like charged; neutrally)
50.	A discharge can take place through a wire, by contact, or through an _____.	(arc)
51.	A discharge has the effect of _____ the charges.	(neutralizing)
52.	An arc discharge will not take place unless there is a _____ of electrons.	(large excess)
53.	Lightning is the discharge of electrons from the clouds to the earth. It is an example of an _____ discharge.	(arc)
54.	An _____ discharge uses the atmosphere as a conductor for the electrons.	(arc)
55.	A static charge in the air is built up by _____ of air molecules in high winds and clouds.	(friction)
56.	Highly moisterized air is a _____ conductor of electrons.	(good)
57.	Low humidity is a _____ of electrons.	(poor)
58.	Lightning is more likely to take place when the humidity is _____.	(low)
59.	Charges are more likely to discharge and not build up when the humidity of the atmosphere is _____.	(high)
60.	Static electricity is affected by the _____.	(weather)

APPENDIX I

Design of the Examinations

In developing the general experimental design it was recognized that some reliable means of measuring the subject's performance gain was essential. At first it was though that the pre-treatment level of sophistication could be ascertained by counting the number of electrical terms checked off by the subject on the questionnaire. Post-treatment level could then be determined from an examination. Such a test was prepared (Appendix M - Exam D). In addition, a brief quiz was prepared to test Ss on the pre-learning material (Appendix M - pre-learning quiz).

Preliminary experimental trials indicated that the examination did not cover in sufficient detail the material taught. Further, there was doubt as to the reliability of the pre-treatment sophistication index since there did not seem to be a lawful relationship between Ss scientific background and number of items checked on the questionnaire. The design was changed to one which employed two parallel item examinations: a pre - and a post-treatment test. The tests were made up of similar items. However, the sequence of questions was different and auxiliary details such as diagrammatic configuration, numerical constants, phrasing, etc. were altered in many questions to minimize carry-over of recall between exams.

A special experiment was conducted to determine the equivalence of the two exams. A group of Ss was given the pre-learning material. Then half the group took Exam A (which was to be used as the pre-treatment exam) and the other half took Exam B (post-treatment exam). Next, a lecture was delivered to the whole group covering the same body of material as was programmed for the machines. Finally, the group was given the second exam. The half that had taken Exam A now took Exam B and those who had Exam B were given Exam A. Results were analyzed on the basis of performance gain. Analysis showed the following:

Table 29

Comparison of the Pre - and Post-Treatment Examinations.

	Exam A first	Exam B first
Mean performance gain	8.15	8.76
Standard deviation	3.4	4.1

The obtained t comparing the above means had a probability of occurring 60% of the time by chance alone.

In the discussion that follows, only the first of the two exams (Exam A) will be considered.

The examination was designed to test Ss in three broad areas:

(1) Pre-learning Material. The pre-learning quiz had performed the function of testing Ss for this subject matter in the original experimental design.

It was decided to incorporate some of these questions into the examination and discard the quiz.

(2) Rote Learning Material. The examination included items designed to determine the effectiveness of the training method in teaching rote material. This includes definitions and simple mathematical calculations.

(3) Transfer Learning Material. Items were included to determine the effectiveness of the training method in teaching concepts. This implies not merely a verbatim memorization of the material, but an ability to apply the concept to the solution of a similar problem. It was desired that Ss demonstrate their insight both by essay answers and solution of circuit problems of an advanced nature.

The number of questions in the exam was increased over Exam D to cover the three areas, pre-learning, rote and transfer more fully. Since an experimental run could not exceed three hours per subject an exam of 19 questions was designed.

For purposes of comparison the questions in the two exams which correspond to one another are as follows:

Exam A	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Exam B	4	3	5	2	6	7	1	10	9	8	11	17	19	16	12	15	14	13	18

For purposes of experimental analysis, the questions were grouped into the three areas as follows:

Area	Question	Points
Pre-learning	1 - 5	5
Rote	6, 7, 8, 11b, 12, 13b, 14, 15 17b, 18, 19	18
Transfer	9, 10, 11a, 13a, 13c, 16, 17a	16
		39 Total

Question 13 is presented as two parts. But for purposes of grading, it was subdivided as follows:

a) 1 point for solving the series circuit.
b) 1 point for calculating voltage drop (on the basis of the answer to part A).
c) 1 point for summing the E.M.F.'s.

Question 11, part b requires a knowledge of Kirchhoff's Laws in order to find V_c and V_d. This was included to detect which Ss were highly sophisticated. In the actual grading of the exams, only the results for V_a and V_b were considered, while V_c and V_d were not.

In developing the form of the exams, it was known that the same sets of tests were to be used for all Ss regardless of the teaching treatment. Since groups of Ss would be taught by either multiple-choice, true-false, or completion items, the exams were designed so that all three forms of questions were included. In addition to such short-form questions, essay-type of questions were also included to test for verbalization of concepts taught.

Analysis of Exam Questions.

The following outlines how the questions relate to the various bodies of material taught and whether they examine for rote or transfer learning. (R) Indicates rote and (T) transfer learning.

1) Pre-Learning: Questions 1 - 5 (R). These are rote questions to take the place of the discarded pre-learning quiz.

2) Circuits: Although this was defined in the pre-learning material it was desired to check whether this information could be used to transfer the concept.

Question 14 (R) The rote definition.

9 (T) Application of the definition to a diagrammatic representation.

16 (T) Ability to verbalize the transferred concept.

3) Ohms Law: All questions check rote learning only. One question tests for definition while the other three test for numerical application of each of the three Ohm's Law formulae:

Question 6 (R) - definition

19 (R) - ($R = \frac{E}{I}$).

8 (R) - ($E = I \times R$).

13a (R) - ($I = \frac{E}{R}$)

4) Voltage Drop: The questions check rote learning only.

Question 17b (R) - definition.

13b (R) - calculation for a simple circuit.

11b (R) - calculation for a complex circuit.

5) Operation of a battery: Question 18 (R) - definition.

12 (R) - diagrammatic representation.

10 (T) - verbalized transfer.

13c (T) - EMF's in series.

6) Resistances in series: Question 15 (R) - diagrammatic identification of resistances in series.

Questions 7, 11, and 17 require Ss to identify resistances in series and then to transfer by equating currents through these resistances.

Question 7 (T) - consists of 2 series resistances in a closed loop.

Question 17a (T) - 2 series resistances in a closed loop, but through an interposed battery.

Question 11a (T) - same as #17a except a numerical answer is required.

APPENDIX J

Attitude of Subjects toward the Skinner Teaching Machine

Every subject using the teaching machine received a protocol, after the learning session and before he had received the second exam, to determine his attitude toward the machine. The protocol consisted of 9 items. Seven of these items were multiple choice, two were open-end questions (Appendix K). All were scored on a point-scale system with a high score indicating favorable attitude. The maximum score possible was 38, the minimum zero.

The following table shows subject scores on the protocol.

Table 30

Subject Protocol Scores as a Measure of Attitude to the Teaching Machine

Multiple Choice		True-False		Completion	
Random	Sequential	Random	Sequential	Random	Sequential
-	13	10	13	28	22
25	23	9	24	16	11
12	-	26	22	23	21
26	31	-	20	23	16
16	20	25	32	27	29
30	17	17	25	29	28
19	14	7	12	30	18
25	27	8	18	13	23
18	25	27	16	14	28
13	17	14	17	31	19

Note: Inadvertently three protocols were not elicited. These are indicated in the above table by a line instead of a protocol score.

Table 31 below lists the mean protocol scores of subjects:

Table 31

Mean Protocol Score of Treatment Groups

Using the Skinner Teaching Machine

Completion		Multiple-Choice		True-False	
Random	Sequential	Random	Sequential	Random	Sequential
23.5	21.5	18.4	18.7	14.3	19.9

A factorial analysis of variance was made of subject protocol scores to determine whether subject attitude to teaching machines is a function of the type and sequence of the programming. The results of the analysis are as follows:

Table 32

Analysis of Variance of Protocol Scores

Source of Variation	df	MS	F
Between Treatments	2	97.14	2.24
Between Random and Sequential	1	6.75	
Treatment	2	44.00	
Within	51	43.30	
Total	56		

The obtained F ratio of 2.24 Between Treatments is not significant. It might be noted that the true-false programming had the lowest learning efficiency as measured by number of responses, the lowest average total performance gain, a rote performance gain equal to the other groups, the lowest transfer performance gain and the least average favorable scores on the protocol. Again, it must be emphasized that all of these comparisons were not statistically significant except the first one mentioned, learning efficiency.

The following table gives the manner in which subjects answered each of the questions on the protocol.

Table 33

Subject's Responses to Protocol

Protocol Questions	Number of Subjects Giving Response								
				Multiple Choice		True-False		Completion	
	Grand Total	Total Sequ'l	Total Random	Sequ'l	Random	Seq'l	Random	Sequ'l	Random
1. The machine is a (an)_______ teacher.									
Excellent	9	2	7	0	1	2	1	0	5
Good	20	14	6	7	3	2	1	5	2
Fair	23	12	11	2	5	6	4	4	2
Poor	2	1	1	0	0	0	0	1	1
Can't teach	3	0	3	0	0	0	3	0	0
2. The machine can teach:									
Insightful Material	21	10	11	4	3	3	3	3	5
Memorization, not insight	28	13	15	4	5	6	6	3	4
Review only	8	6	2	1	1	1	0	4	1
Cannot teach	0	0	0	0	0	0	0	0	0
3. Machine is an interesting way to learn.									
Yes	42	25	17	7	6	9	4	9	7
No	15	4	11	2	3	1	5	1	3

Table 33 (Continued)

Protocol Questions	Grand Total	Total Sequ'l	Total Random	Multiple Choice Sequ'l	Multiple Choice Random	True-False Sequ'l	True-False Random	Completion Sequ'l	Completion Random
4. Feelings on using machine in classroom									
Don't	21	11	10	5	4	3	4	3	2
Think not	7	4	3	1	0	3	2	0	1
Maybe	12	7	5	2	2	3	3	2	0
Yes, but	7	4	3	0	0	0	0	4	3
Yes	10	3	7	1	3	1	0	1	4
5. Did the material follow a logical sequence?									
Never	0	0	0	0	0	0	0	0	0
Almost never	1	0	1	0	0	0	1	0	0
Sometimes	16	8	8	2	4	5	2	1	2
Almost always	25	11	14	4	4	3	4	4	6
Always	15	10	5	3	1	2	2	5	2
6. I would like to study on my own in this way_____% of the time.									
0%	3	1	2	0	0	0	2	1	0
10%	14	8	6	4	2	2	2	2	2
25%	13	7	6	1	1	3	2	3	3
50%	11	5	5	1	5	3	1	1	0
75%	13	6	7	1	1	2	2	3	4
100%	3	2	1	2	0	0	0	0	1

Table 33 (Continued)

Protocol Questions	Grand Total	Total Sequ'l	Total Random	Multiple Choice		True-False		Completion	
				Sequ'l	Random	Sequ'l	Random	Sequ'l	Random
7. Teaching machines can replace teachers____% of the time.									
0%	26	14	12	3	2	6	5	5	5
10%	13	5	8	2	4	1	2	2	2
25%	8	4	4	2	2	1	0	1	2
50%	10	6	4	2	1	2	2	2	1
75%	0	0	0	0	0	0	0	0	0
100%	0	0	0	0	0	0	0	0	0
8. Teaching machines can substitute for:									
Textbooks	15	8	7	4	3	1	2	3	2
Visual & Auditory aids	16	10	6	2	3	5	1	3	2
Discussions	5	2	3	1	0	0	0	1	3
All of the above	1	1	0	0	0	0	0	1	0
Nothing	20	8	12	2	3	4	6	2	3
9. Opinion in general - Attitude to machine, presentation, material:									
No good	2	0	2	0	0	0	2	0	0
For memory, not understanding	10	6	4	3	2	2	2	1	0
For review, facts	23	13	10	3	3	4	3	6	4
Good, but...	11	7	4	3	1	2	0	2	3
Great	11	3	8	0	3	2	2	1	3

The first item gave the subjects the opportunity to rate the machine as a teacher. 9 subjects rated it excellent, 20 good, 23 fair, 2 poor, and 3 said the machine cannot teach.

The second question was concerned with the ability of the machine to teach insightful or memorization material: 21 subjects said the machine can teach insightful material, 28 said it can teach only memorization, 8 said it can present review material but cannot teach memorization or meaningful material, and no subjects said it cannot teach. 2 of the 3 subjects (all true-false, random material) who said on item 1 that the machine cannot teach said on item 2 that it can teach only memorization; one said it can present review material only. A possible explanation for this discrepancy is that the Ss may have felt that memorization and review are not real learning and therefore the machine cannot (according to their definition) actually teach.

42 of the subjects said the machine was an interesting way to learn, 15 said it was not.

Answers in response to the question "Suggestions have been made to use the teaching machine for classroom use. What are your feelings on this?" were sorted into groups, the general headings of which and the numbers of subjects in each were: "don't use it" - 21, "think not" - 7, "maybe, but use is limited" - 12, "yes" definitely" - 10.

More specifically, some of the comments in each group were as follows:

"Don't use it" (21): - 8 subjects referred to the questioning student - explaining teacher relationship as definite, essential and necessary. A few favored the machines only for review; a few felt that the machine can teach unassociated facts, not theories, and therefore does not lead to true learning. Several pointed out that the questions can be answered by writing the response to the number, not to the content, of the question. Some criticized the machine as being tedious, tiring, and hard to read. Other comments were: 'don't do it', 'inadequate', 'too impersonal', 'only for nitwits', 'it sounds horrible', and 'a game, a novelty, and not a true instrument of educational advance'.

"Think not" (7):- Subjects in this group felt that the machines could not teach students to understand material, but were adequate for memorization, review, and practice. One pointed out that the machine requires the student's cooperation; that boredom and possible cheating would defeat the method's purpose. Subjects felt that nothing can replace the stimulating insight, understanding, and knowledge of a teacher. One wrote "Its purpose can be served by a teacher but it cannot take the place of a teacher."

"Maybe, but uses limited" (12) - Subjects in this group said the machine would be most useful for review and memorization, and that it can teach subjects like mathematics science, and languages, but would be dull and ineffective for literature, philosophy, or social and classroom discussions. It was suggested that the novelty would be an aid, that the machine is more suited to individual than to classroom use and that it needs to be perfected.

"Yes, but mentioning reservations" (7): - Subjects in this group felt that the machine can be of great value in certain subjects and under certain conditions. It can review, clarify and crystallize concepts, especially after a class discussion, and it makes the student concentrate. However, it cannot answer questions, is tiring to use for long periods, and takes too much time. In general, students can can learn facts, but close contact with a teacher is more conducive to learning.

"Yes" (10): - Subjects in this group said that the machine is interesting, very useful, helpful, a good way of learning new material, excellent for memorization and great for cramming. One said simply "I'm for it". Others commented that the machine can help teachers, make students feel more adequate, manage checking, review, memorizing, and is useful even for insightful material (if background material has been given). One subject called the machine a "benefit to our educational society", and another called it an "excellent but impractical idea".

Half of the subjects received the material in systematic order and half received it in random order. The protocol scores on the question of whether the material followed a logicial sequence did not correlate with the method of presentation. No subject, either sequential or random, said that the material never followed a logical sequence. One random subject said "almost never".

Eight sequential and 8 random subjects said sometimetimes.

11 sequential and 14 random subjects said almost always.

10 sequential and 5 random subjects said always.

Several of the subjects commented that they were unfamiliar with the subject of electricity, and therefore could not tell whether the material was in logical sequence. They said they thought "sometimes". It is surprising that many subjects chose "almost always" or "always" rather than "sometimes" or "almost never". It is possible that, being unfamiliar with the subject, they tried to learn each item of information in the order it was presented. It did not seem "sequential" or "random" to them, as they had no preconceived notion of the structure or interrelationship of the topics. Faced with this item in the protocol, they assumed that the material had been presented logically, as this is the usual teaching procedure. Three subjects said they would never like to study on their own in this way, 14 said they would like to 10% of the time, 13 said 25%, 11 said 50%, 13 said 75%, and 3 said 100%. 68% of the subjects said the machine can replace a teacher 0 - 10% of the time, (26 subjects said 0% and 13 said 10%) and 32% said the machine can replace a teacher 25-50% of the time (8 subjects said 25% and 10 said 50%. None said over 50%.

To the question of what educational aids the machine can substitute for, 15 subjects said textbooks, 16 said visual and auditory aids, five said discussion periods, one said all three of these, and 20 said none of these.

The last item on the protocol was: "Please write down any thoughts you may have on the material, its presentation or organization, or on the teaching machine". The subjects' answers were sorted into groups. Two subjects said the machines were useless; one said he knew the information already and that the machine cannot teach, the other said she felt she was guessing all the time.

Ten subjects said that they had learned but objected to the lack of personal explanation. One said "humans teach, not machines". Some said that they had answered on the basis of having remembered, not understood, the answer. One commented, "by using this machine one only creates parrots and other machines - not human beings who are capable of thinking for themselves in a logical manner." A few said it was novel at first, then boring; a few thought it would be adequate for limited amounts of material, but not for a term's or a year's work. Some felt they would soon forget what they had just learned.

Twenty-three subjects said that the machine was best for rote memorization or for review, or that it would teach facts but not theories. Several suggested that it might help to determine specific aptitudes or abilities.

Eleven said the machine was good, but objected to one or more of these features: lack of discussion, mechanical difficulties, physical discomfort, rapid forgetting of material learned, individual differences in learners' needs, interests, and areas of difficulty.

Eleven subjects said that the machines were excellent and that they had learned a great deal. Some expected to retain what they had learned. Others added that they found the procedure interesting. Several of the subjects in this group commented, despite their favorable opinion, that the machine cannot replace a teacher, who can answer students' questions and can give further explanation.

Relationship of Ss attitude and Performance Gain.

The subject's protocol scores were unrelated to difference between pre- and post-examination scores. A correlation of (r) of .16 was not significantly different from zero (appendix N). It might be expected that there would be a positive relationship between a subject's improvement on the post-examination and his opinion of the machine; that is, if a subject learned a great deal he would have a favorable opinion of the teaching machine. However, it appears that this was not the case. The protocol was given before the post-examination, so the subjects answering the protocol were unaware of the amount they had learned. It is possible that if the protocol had been given after the post-examination the correlation would have been higher as subjects might have been made aware of the amount that they had learned. Since the unbiased opinion of subjects to the teaching machine was desired, the administering of the protocol before the post-examination would render less contaminated results.

A subject could learn although he rated the machine as uninteresting, felt it was inadequate for classroom use, would not like to study with it on his own and/or felt it could not replace teachers and books. Conversely, a subject might be enthusiastic about the possibilities of the machine and yet not learn enough to do well on the 1st examination.

Considering the fact that the machine presents material in an incremental manner, it is to be expected that subjects who usually employ broader, more cognitive methods of synthesized study habits would be opposed to the teaching machine. These subjects might very well show improvement on the second exam but score low on the protocol because they objected to the teaching technique of the machine. A subject who normally preferred to learn in an incremental manner might score high on the protocol because he liked the teaching technique, but might score low on the post exam.

In conclusion, the subjects felt that the machines are adequate for review or for teaching rote memorization or simple facts. They are not suitable for teaching theories. The three most recurring criticisms are the lack of teacher-student relationship; the lack of opportunity to ask questions and receive additional explanation; and the tendency to respond to difficult questions on the basis of a remembered rather than an understood answer. Subject protocol scored need not vary and do not vary in relationship to subject performance gain.

APPENDIX K

Materials Used In Experiment I and II

1. Questionnaire

NAME:

ADDRESS:

TELEPHONE NUMBER:

CLASS:

OCCUPATION:

AGE:

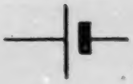
SEX:

1. HAVE YOU EVER TAKEN A COURSE IN OR STUDIED ANY OF THE FOLLOWING SUBJECTS? (PLACE A CHECK MARK)

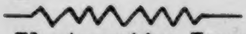
SUBJECT	HIGH SCHOOL		COLLEGE		ARMED SERVICES		OTHER	
	yes	year	yes	year	yes	year	yes	year
GENERAL SCIENCE								
PHYSICS								
ELECTRICITY								
ELECTRONICS								

2. CHECK WHICH OF THE FOLLOWING CONCEPTS OR SYMBOLS YOU KNOW.

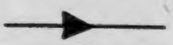
Electron
I
Voltage
Battery
Ampere
Current flow
Ohms
E

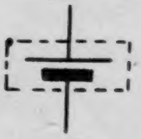


R



Electromotive Force
Resistance
Free Electrons
Open Circuit
Closed Circuit

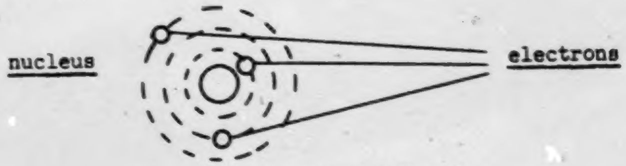




2. Pre-Learning Material

This is preliminary background material to the material to be learned through the teaching machine. Some of the attached material may already by be familiar to you. You may know more details of the subject than is included here. However, a lot of information has been compressed into the brief space of these few pages. Therefore, please study the material carefully. You will be asked to take a brief quiz before proceeding with the experiment.

All the effects of electricity can be explained and predicted by assuming the existence of a tiny particle called the electron. WHAT IS THE ELECTRON - ALL substances and materials are composed of small particles called atoms. These atoms in turn consist of electrons revolving in orbit around a nucleus.



THE ATOM

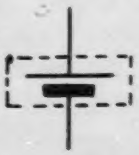
Each source of electricity is produced principally in the same way; by forcing electrons out of their normal orbits in the atom, thus creating "free" force electrons out of their orbits, some kind of energy is required. One source of such energy or electrical force is a battery.

There is in nature a physical law which compels free electrons to seek out a place where there is a lack of electrons, and to move there. However, there must be a path along which they can flow. This path can be provided by a piece of wire, or some other material. The essential point is this: if we have an accumulation of free electrons at one place and a lack of electrons at some other place, and provide a path betwen the two, electrons will flow. This flow of electrons is called an electrical circuit.

Components of an Electrical Circuit

A. Electromotive force - EMF

1. Unit of measurement: Volt
2. Symbol representing EMF in a formula: E
3. Symbol representing EMF in a diagram:



4. To move any object - solid, liquid or gas - you must put pressure or force behind it. In just the same way you must apply a force - an "electromotive" force - to cause electrons to move. Electrical pressure or force is measured in "volts" and is called electromotive force. A battery is a source of electromotive force and when it is "hooked up" it will "push" electrons through the circuit.

B. Current

1. Unit of measurement: Ampere

2. Symbol representing current in a formula: I

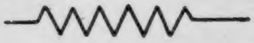
3. Symbol representing current in a diagram: (an arrow) →

4. Electrical current is the flow of free electrons. Just as "gallons per minute" is the standard measure for indicating water flow, so the "ampere" is the standard measure for indicating the number of electrons that flow past a given point in a second.

C. Resistance

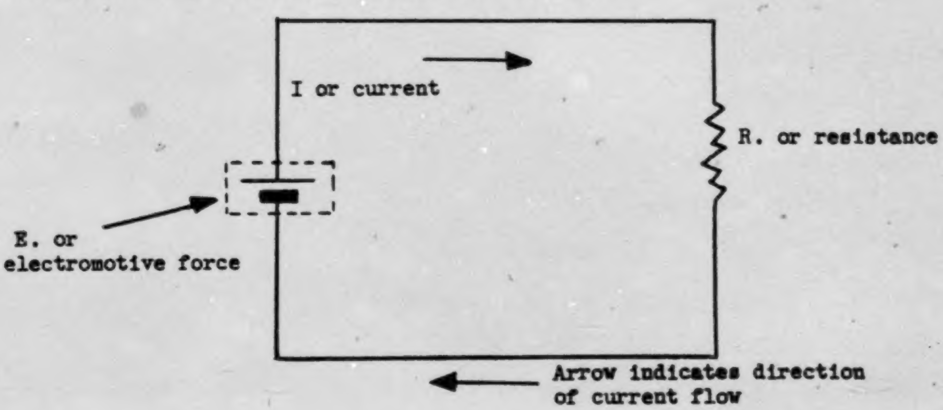
1. Unit of measurement: Ohms

2. Symbol representing resistance in a formula: R

3. Symbol representing resistance in a diagram: 

4. Resistance is a measure of how easily a material gives up free electrons. In a sense then, a material will oppose the flow of electrons through it, depending on how tenaciously it clings to its free electrons. Every type of material exerts some opposition to current flow, whether large or small, and this opposition to current flow, is called "resistance." For example, metal wire "gives up" electrons easily and therefore offers little resistance to the flow of electrons. In contrast, rubber does not give up electrons easily and offers a substantial resistance to the flow of electrons. The standard for measuring the degree of resistance of a material is called the Ohm.

D. Components represented as a schematic drawing:



Arrow indicates direction of current flow

NAME: ______________________

____

3. Pre-Treatment Examination

INSTRUCTIONS

1. Some of the questions you may not be able to answer.
2. You may take as much time on this examination as you need.
3. Please do all calculating in the space next to the question you are answering.
4. If you have any questions, ask the experimenter.

---

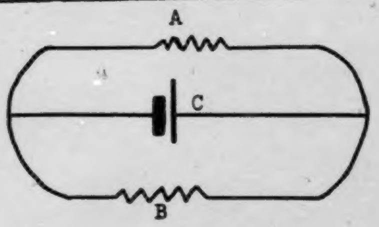
1) E represents ____________ a) energy b) voltage drop c) E.M.F. d) electrons

2) Identify the following:

A.______________________

B.______________________

C.______________________



3) The flow of ________________________ in a wire produces an electrical ~~c~~ current.

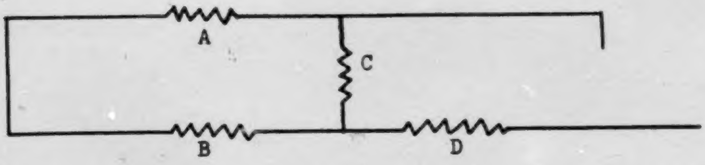
4) The Resistance is measured in amperes. TRUE FALSE

5) A battery is a source of ______. a) current b) E.M.F. c) magnetism d) bound electrons

6) The resistance of an electrical component can be calculated if both the______________ and ________________ are known.

7) Of the resistances shown in the diagram, ___________ are in series.

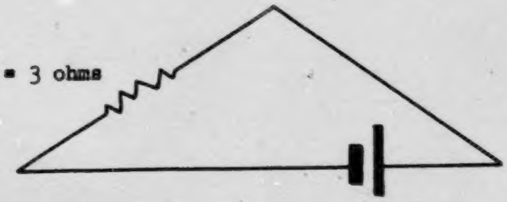
a) B & D b) none c) A & B d) A, B, & D



Calculations

8)

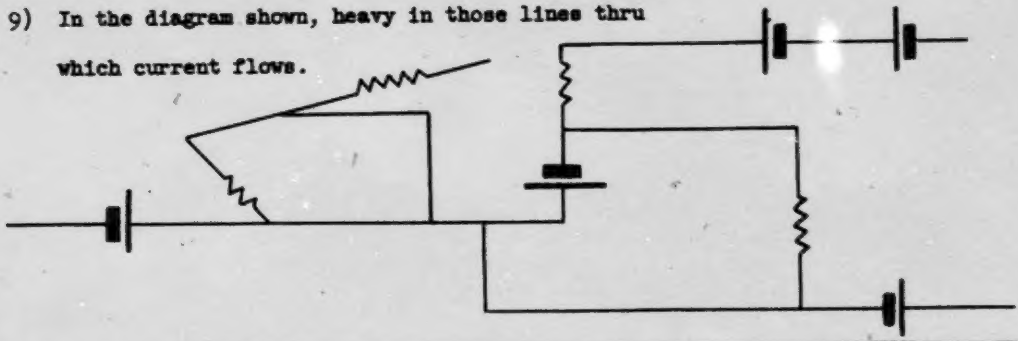
R_a = 3 ohms



EMF of the battery is ______

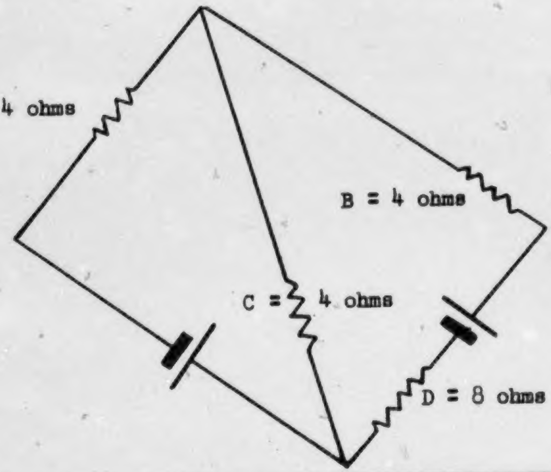
if I = 12 amps.

9) In the diagram shown, heavy in those lines thru which current flows.



10) On the basis of the internal operation of a battery, explain why a portable radio with a "dead" battery will not play. ________________________

11)


A = 4 ohms
B = 4 ohms
C = 4 ohms
D = 8 ohms

a) I_a = 8 amps

I_b = 3 amps

Current thru D is ______

b) V_a = ______

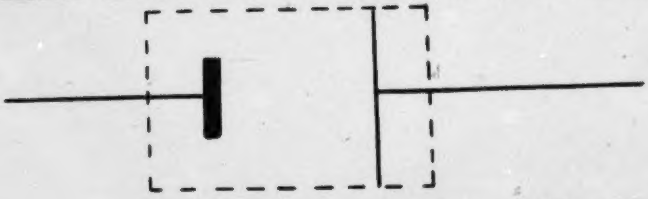
V_b = ______

V_c = ______

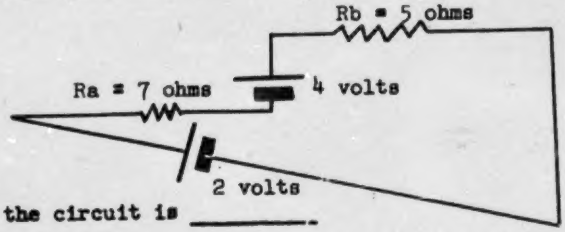
V_d = ______

---

12) Indicate the direction of electron flow inside the battery.



13)


Rb = 5 ohms
4 volts
Ra = 7 ohms
2 volts

a) The current in the circuit is ________.

a) 2 amps b) 18 amps c) ½ amp d) not calculable

b) Voltage drop across B is ____________

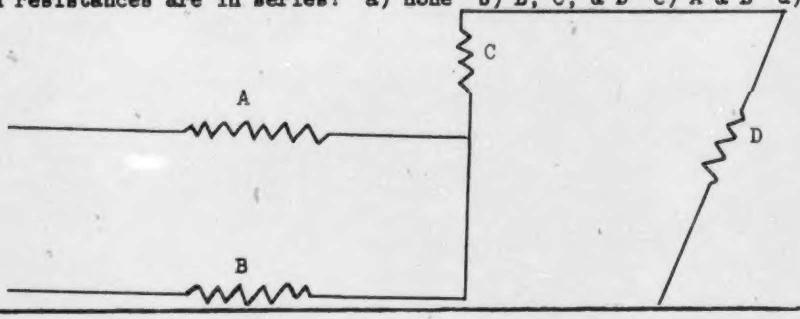
---

14) The two conditions a) complete path for electron flow and b) source of E.M.F., define __________________.

a) Kirchhoff's Law b) a series circuit c) a network

d) an electrical circuit

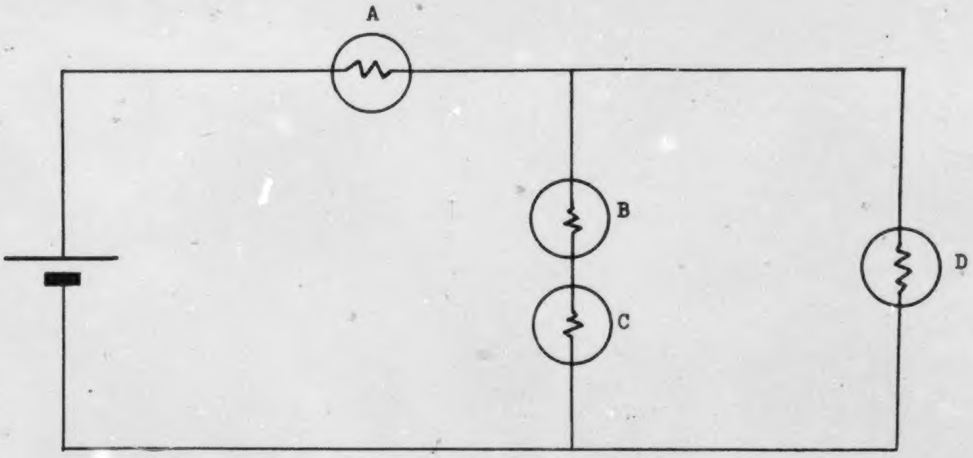
15) Which resistances are in series? a) none b) B, C, & D c) A & B d) C & D



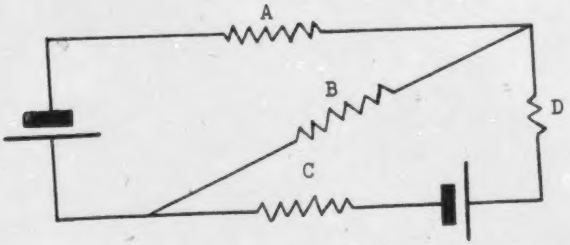
16) The diagram shows a circuit with four electric light bulbs. If bulb C burns out it is known that bulb B will not remain lit. a) Why? Give a complete answer. ________

b) Will bulb A remain lit? YES NO MAYBE

Will bulb D remain lit? YES NO MAYBE



17)



Note: All resistances are equal

a) Resistances ___ & ___ have the same current flowing thru them.

b) Circle which of the following voltage drops, if any, equal each other:

V_a. V_b. V_c. V_d. none.

---

18) a. Inside a battery, electrons flow from the excess to the lack terminal.

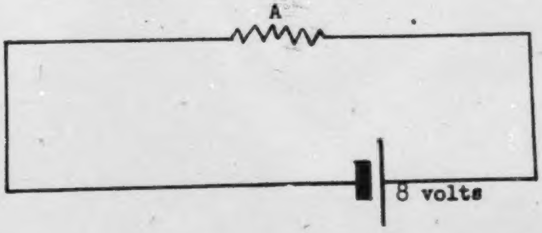
TRUE FALSE

b. A battery employs magnetic action to create an E.M.F.

TRUE FALSE

---

19) In the circuit shown, current equals 2 amperes. The resistance of A, expressed in the proper units, equals ____________.



4. PROTOCOL

NAME:

You are being asked to give your opinion of the applications of teaching machines. Please circle your answer. Feel free to make any additional comments next to any question. The information here will remain strictly confidential.

1) a. The machine is an excellent "teacher".
   b. The machine is a good "teacher".
   c. The machine is a fair "teacher".
   d. The machine is a poor "teacher".
   e. The machine cannot teach.

2) a. The machine can teach insightful material.
   b. The machine can teach memorization but not "meaningful" material.
   c. The machine can present review material but cannot teach memorization or meaningful material.
   d. The machine cannot teach.

3) I found machine presentation of the material an interesting way to learn.
   a. Yes
   b. No.

4) Suggestions have been made to use the Teaching Machine for class room use. What are your feelings on this?

5) a. The material never followed a logical sequence.
   b. The material almost never followed a logical sequence.
   c. The material sometimes followed a logical sequence.
   d. The material almost always followed a logical sequence.
   e. The material always followed a logical sequence.

6) I would like to study on my own in this way 0%, 10%, 25%,50%,75%,100%

7) Teaching machines can replace teaching 0%, 10%, 25%, 50%, 75%, 100%

8) The teaching machines cannot replace teachers but can substitute for:
   a. text books
   b. visual and auditory educational aids (e.g. films)
   c. discussion periods
   d. 1, 2 & 3
   e. nothing else

9) Please write down any thoughts you may have on the material, its presentation or organization or on the teaching machine. Thank you.

5. POST-TREATMENT EXAMINATION

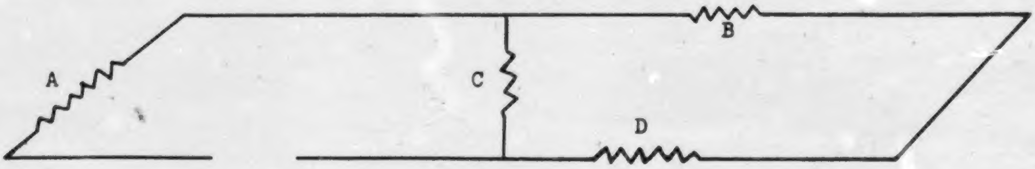
NAME:____________________

INSTRUCTIONS: PLEASE DO ALL THE CALCULATIONS in the space provided next to the question. You may take as much time on this examination as you need. If you have any questions, as the experimenter. Answer all questions.

---

1. Of the resistances shown in the diagram, _____________ are in series.

a) B & D b) none c) A & B d) A, B, & D

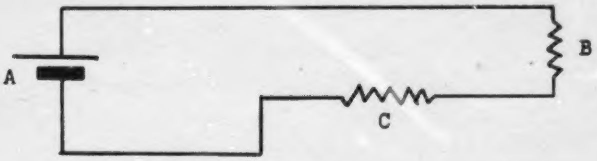


---

2. The resistance is measured in volts. TRUE FALSE

---

3. In the following diagram, A is a ______________, B is a ______________ and C is a ______________.



---

4. The symbol E. represents ______. a) Energy b) Voltage drop c) EMF d) electrons

---

5. It is the flow of _______ that produces an electrical current.

---

6. A battery is a source of ____________. a) current b) EMF c) magnetism d) bound electrons

---

7. The resistance of an electrical component can be calculated if both the _________________ & ___________________ are known.

8. A flashlight with a "dead" battery will not light. On the basis of the internal operation of a battery, explain why. ________________________

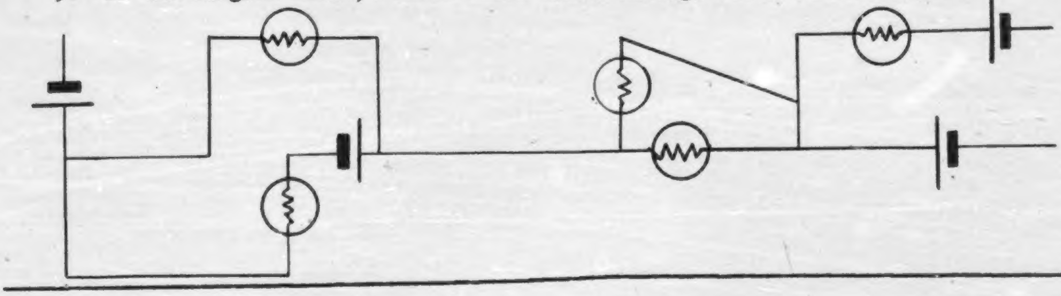
____

____

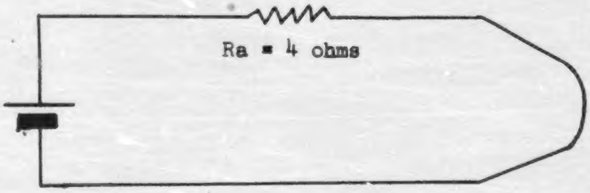
____

---

9. In the diagram shown, redraw those lines through which current flows.

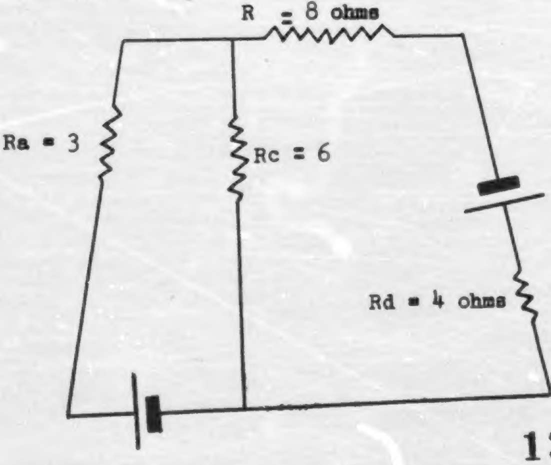


10.



EMF of the battery is __________ if $I = 12$ amps

11.



a) I - 8 amps
I_b - 3 amps
Current thru D is ______

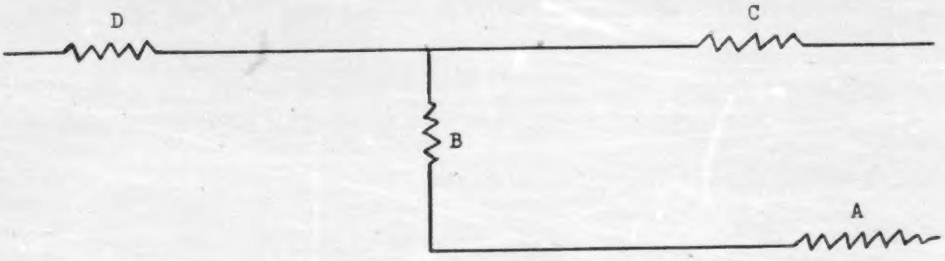
b) V_a = __________

V_b = __________

V_c = __________

V_d = __________

12. Which resistances are in series? a) none b) B, C & D



---

13. a) Inside a battery electrons flow from the excess to the lack terminal.

TRUE FALSE

b) A battery employs magnetic action to create an EMF

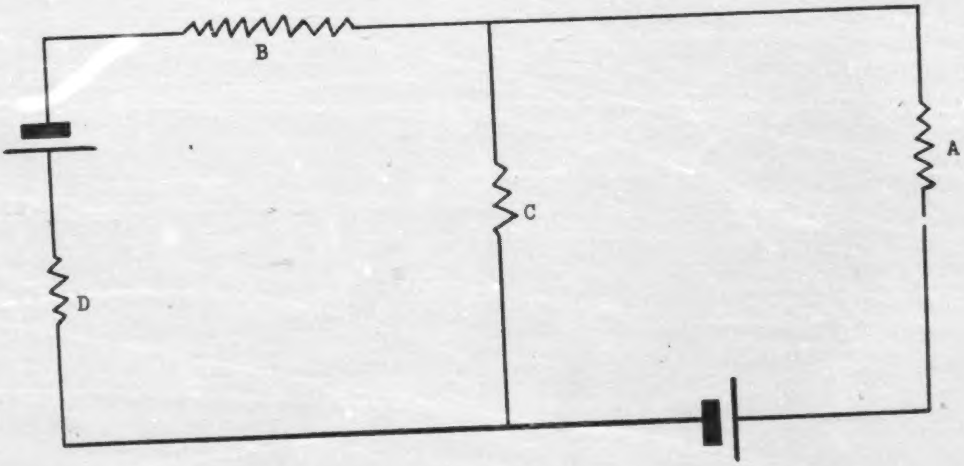
TRUE FALSE

14.

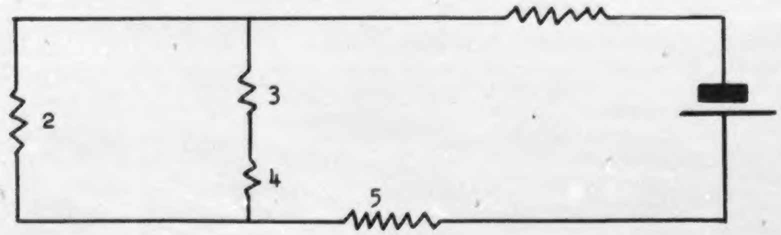
Note: All resistances are equal.

a) Resistances ___, & ___ have the same current flowing through.

b) Circle which of the following voltage drops, if any, equal each other: V_a V_b V_c V_d none



15. An auditorium is cooled by five electric fans which are connected as shown in the diagram.



Suppose fan #3 develops wiring trouble so that current cannot flow through it.

a) Will fan #4 continue to operate? Why?________________

____

____

____

b) Will fan #5 continue to operate? Why?________________

____

____

____

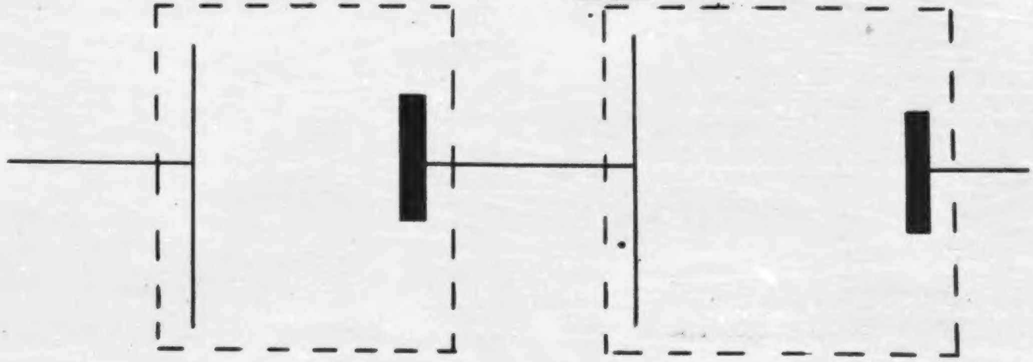
---

16. Every electrical circuit must contain __________ and _______.

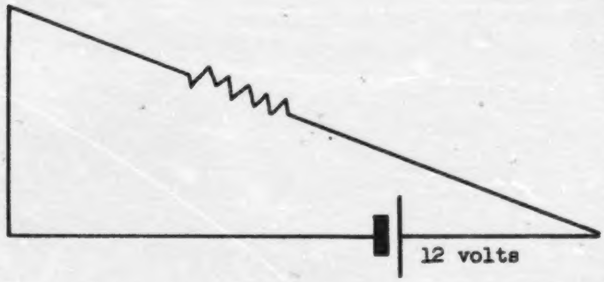
a) a network b) a source of EMF c) a switch d) a complete path for flow of electrons e) an alternating magnetic field.

---

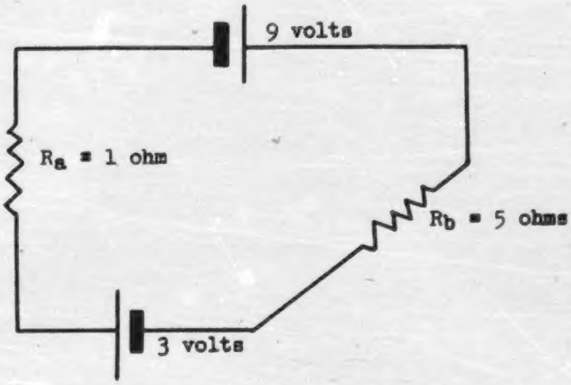
17. What is the direction of current flow inside the batteries shown?



18. In the circuit shown, current equals 2 amperes. The resistance of A, expressed in the proper units, equals ________.



19.


9 volts
Ra = 1 ohm
Rb = 5 ohms
3 volts

a) The current in the circuit is ________

a) 2 amps b) 18 amps c) ½ amp d) not calculable

b) Voltage drop across B is ________

APPENDIX L

Text Material Used in Experiment II

An electrical circuit exists whenever two conditions are fulfilled: 1) A complete path for flow of electrons, and 2) A source of electromotive force. A complete path is necessary so that there is a continuous circulation of electrons. The rate of flow of electrons is called current and is measured in amperes. The function of the electromotive force is to push electrons through any resistance they may encounter along the path of flow. An electrical circuit is defined by 1) A complete path for current flow; 2) A source of electromotive force (E.M.F.). Also associated with a circuit are three measurable quantities: current, resistance and E.M.F. Like all quantities, they must be expressed in the proper terms or units. In electrical circuits, these units are:

Current (I) - amperes
Resistance (R) - ohms
E.M.F. (E) - volts

In the physical world around us we find many examples where force is related to resistance. For instance, in driving a nail into a piece of wood, the blow of the hammer is opposed by the resistance of the wood to the nail. Intuitively we know that the heavier the blow, the deeper the nail will penetrate. Conversely, the greater the resistance of the wood, the shallower the penetration. As another example, in operating a motor boat, the speed of the boat depends on the relationship between driving force of the propeller and the resistance of the water. As a final example, we consider the operation of a flashlight. In this case the flow of the current will depend on the magnitude of the battery's electromotive force and on the resistance of the light bulb in the flashlight. All three examples are similar in that the resulting effect depends on *both* the force and the resistance involved. Thus: if a heavier hammer is used, the nail will penetrate deeper, and if a battery of greater EMF is used, the current in the flashlight will increase.

In an electrical circuit, the interdependence among EMF, resistance and current can be expressed mathematically by Ohm's Law. This law states that current is *directly* proportional to EMF, but *inversely* proportional to resistance. In equation form, this reads:

$$\text{current} = \frac{\text{E.M.F.}}{\text{resistance}}$$

In symbols: $I = \frac{E}{R}$

The relations and proportions established in this equation determine what happens to current, EMF and resistance, when any one of these is changed. For instance, if you look at the formula $I = \frac{E}{R}$, you can see that to double the current through a given resistance (where the resistance remains constant), the EMF must be doubled. You can also double the current by keeping the EMF constant and by *halving* the resistance.

In using Ohm's Law, all quantities must be expressed in their proper units: $\text{amperes} = \frac{\text{volts}}{\text{ohms}}$

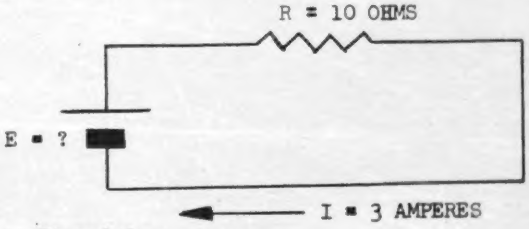
It should be realized that $I = \frac{E}{R}$ is an equation and can therefore be rearranged algebraically to suit our convenience. For instance: $E = I \times R$ is another form of Ohm's Law, while $R = \frac{E}{I}$ is still another.

All these formulas are mathematically identical and it is merely necessary to substitute known values into the appropriate forms and solve for the desired unknown.

Here is an example: What EMF is required to push 2 amps through a resistance of 3 ohms?
Using $E - I \times R$ we calculate the EMF to be:

$$E = 2 \text{ amps} \times 3 \text{ ohms} = 6 \text{ volts}$$

FIGURE 1

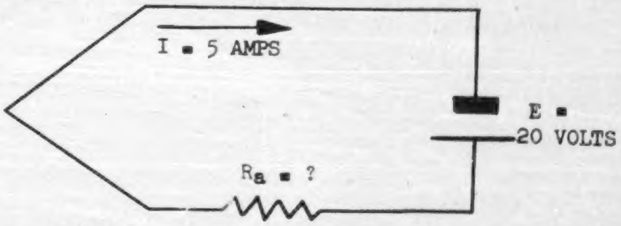


Consider the circuit shown in Figure 1.
What is the battery EMF required to produce a current of 3 amperes?
Using Ohm's Law: $E = I \times r$

$$E = 3 \text{ amps} \times 10 \text{ ohms}$$

Thus, $E = 30$ volts

FIGURE 2



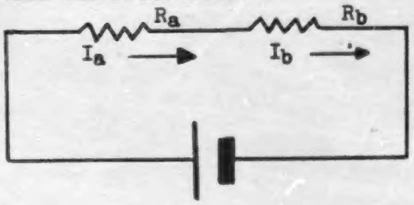
To illustrate the use of the form $R = \frac{E}{I}$,

what is the value of R_a for the circuit shown in Figure 2?

$$R = \frac{E}{I} = \frac{20 \text{ volts}}{5 \text{ amps}} \qquad \text{Thus, } R = 4 \text{ ohms}$$

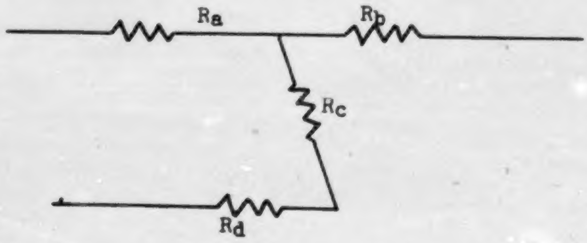
The circuits of figures 1 & 2 are the simplest circuits possible in that they consist of one source of EMF and one resistance. It is possible however, for a circuit to include more than one resistance.

FIGURE 3



If these resistances are connected end to end in chain fashion, as in Fig. 3, it is called a series connection. The important feature of a series connection is that all the current flowing through the first resistance, also flows through the second. That is, if I_a represents current through R_a, and I_b represents current through R_b, then I_a must equal I_b. These currents must be equal because no alternative path is provided for current flow; so all of I_a has no choice but to flow through R_b. It follows: $I_b = I_a$

FIGURE 4

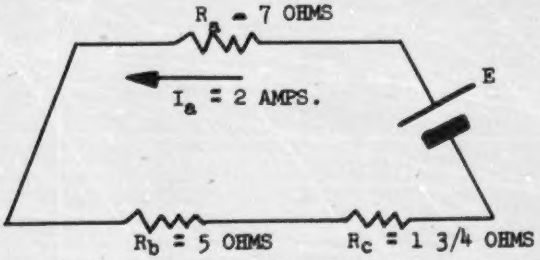


Consider the connections of Figure 4.
Of the 4 resistances shown, C and D are in series because all the current through D must pass through C as well, i.e. there is no other path "branching off" between R_d and R_c for any of the current to flow through.

On the other hand, suppose we examine resistances A and B for connection in series. Not all the current I^a must pass through R_b because a "branch-off" exists between A & B (leading to C). Hence we conclude that A & B are not in series. Considering all other combinations, similar reasoning shows that C & D are the only two resistances in series. It can be stated therefore, that two resistances in series must have the same current flowing through them.

The concept of resistances in series is very useful in solving electrical circuits because it enables us to simplify calculation by immediately equating the currents of any resistances which happen to be in series. To illustrate, Figure 5 shows a circuit with 3 resistances in series.

FIGURE 5



If the current through A is 2 amperes, then without further calculation, we know that both I_b and I_c also equal 2 amperes.

Let us return to the "force - resistance" relationships found in the physical world around us. We know that a force is necessary in order to overcome resistance. This force, however, is used up in overcoming the resistance. We can continue to work against resistance only so long as force is available. For instance, we can drive nails only so long as our arm muscle is not exhausted. It is the same in electrical circuits. Current will flow through a resistance only so long as there is some source which produces an EMF. The quantity of electrical force used up in creating a current flow is called: voltage drop (symbol = V)

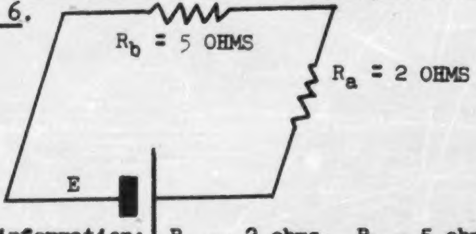
Voltage drop represents the reduction in EMF resulting from pushing current through a resistance. Voltage drop is measured in volts, (as is EMF) and can be calculated from Ohm's Law.

For example, in Figure 5, Ia is known to be 2 amperes. Therefore, to calculate voltage drop, $V_a = I_a \times R_a$

Thus, $V_a = 2$ amps $\times$ 7 ohms $=$ 14 volts

14 volts represents that proportion of the total EMF of the battery expended in pushing current through R_a. Obviously, the magnitude of E must be greater than 14 volts since additional voltage drops are expended through R_b and R_c. (These can also be calculated using Ohm's Law).

The following problem shows how the concepts of voltage drop, series resistances, and Ohm's Law can be combined to analyze a simple circuit, as shown in Figure 6.



We are given the following information: $R_a = 2$ ohms, $R_b = 5$ ohms, $V_a = 6$ volts. We are asked to find the voltage drop in resistance B (V_b).

The first step is to calculate current through resistance A, using Ohm's Law: $V_a = I \times R$

$6 = I_a \times 2$

$I_a - \frac{6}{2} = 3$ amps

Since R_a & R_b are in series, I_b equals I_a
Therefore, I_b equals 3 amps.
Finally, using Ohm's Law once more, $V_b = I_b \times R_b = 15$ volts.
What is the magnitude of E?
E must equal 15 volts plus 6 volts = 21 volts. Can you clearly see why?

As previously mentioned, in order to keep current flowing, it is necessary to provide continuous electromotive force. If the EMF (or electrical "muscle") becomes exhausted, current will cease. A battery is a device which makes available a continuing EMF by means of internal chemical actions. EMF means "A continuous supply of free electrons in one place and a continuous deficit of electrons in another place." Current flows when a path is provided between excess and lack of electrons. A battery, of course, does not provide the path; it provides only an excess - lack relationship of electrons (or EMF).

FIGURE 7

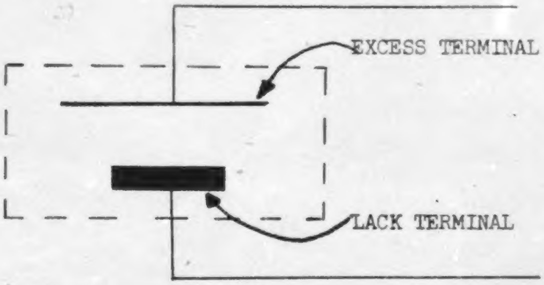
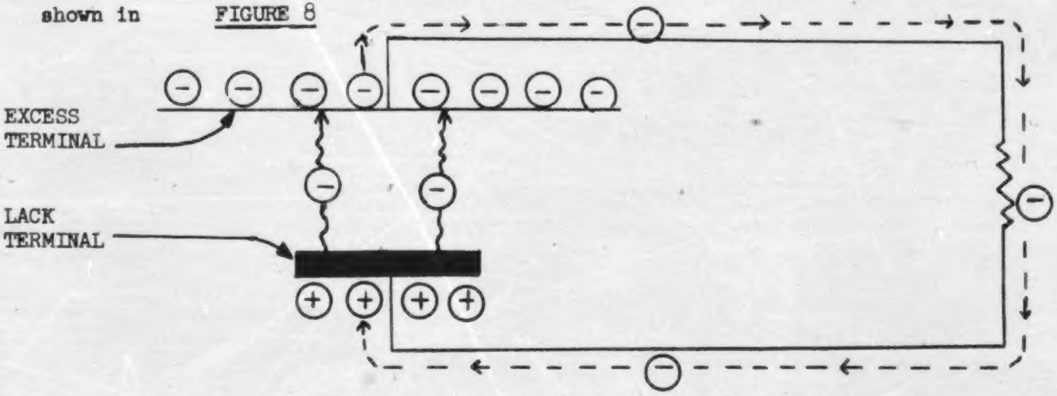


Figure 7 represents a battery diagrammatically.
The long line represents the place where there is an excess of electrons and the short heavy line, a lack of electrons. A battery is able to maintain this unbalance of electrons between terminals because the space between is filled with a chemical substance which is able to keep transferring electrons from the lack terminal to the excess terminal.

In an electrical circuit, the movement of the electrons is as shown in FIGURE 8



The two necessary conditions exist: a complete path for electrons flow and an excess of electrons in one place and lack of electrons in another. The excess electrons leave the excess terminal, flow through the external circuit and arrive at the lack terminal. If there were no means of transferring electrons from lack to excess terminal inside the battery, current would soon cease because excess electrons would flow to the lack terminal until a balance was reached. However, by internal chemical action, the battery continuously transfers electrons so that a continuing unbalance between the number of electrons at one terminal over another is maintained.

The EMF of a battery is a quantitative indication of how rapidly electrons are being transferred from lack to excess terminal. The faster the transfer, the higher the EMF. Thus, the EMF in a circuit can be doubled in either of two ways: we can either replace an existing battery by one that transfers electrons twice as fast, or, add to the circuit a second battery whose EMF is equal to the first. Either of these methods will double the EMF.

APPENDIX M

Material Used Only in Preliminary Experiments

1. Questionnaire

NAME: ______________________________

ADDRESS: ______________________________

TELEPHONE NUMBER: ______________

CLASS: ______________________________

OCCUPATION: ______________________________

AGE: ____ SEX: ________

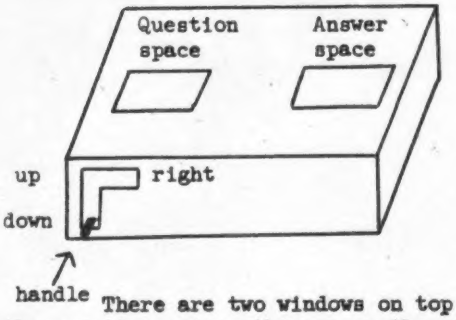
1) Have you ever taken a course or studied the following subjects:

	GENERAL SCIENCE	CHEMISTRY	PHYSICS	ELECTRICITY AND/OR ELECTRONICS
HIGH SCHOOL				
COLLEGE				
ARMED SERVICES				
OTHER				

2) How long did you study the above? Months ____ Year 19____

APPENDIX M

2. Instructions



↑ Move handle to see answer

→ if your answer is correct

↓ to move on to next question

There are two windows on top of the box. The one on the left is the *question space*; the one on the right is for *your answer*. The correct answer appears in the question space *after* you have written your answer in the space on the right. The handle or lever on the front of the box moves the questions and answers ahead.

Do not touch any button, knob or lever until you are sure you understand the directions. Follow them exactly, and treat the machine carefully.

This is what you do:

1) Read the question in the left-hand window. Do not move the handle. Write the *number* of the question and *your answer* to it in the right-hand space.

You are required to supply the missing word or words. If there is a blank line in the sentence, one word is missing. If the line has a vertical mark across it _____/_____, there are two words missing. If the line has two vertical marks across it ______/____/____ there are three words missing.

If you do not know the answer, write the number of the question and "DK" (don't know).

If you want to change or cross out your answer, draw a line through it and write a different answer.

2) Raise the handle - move it definitely and firmly, but gently. This motion uncovers the correct answer in the upper right corner of the question window *after* you have written your answer in the answer space.

3) Look to see if your answer in the right-hand space is the same as the correct answer in the question window.

4) If your answer is correct, move the handle to the *right* - definitely but gently. Then move it to the left and downward.

If your answer is wrong, do *not* move the handle sideways, but move it straight down to starting position.

5) The downward motion moves the next question into position in the question window and also moves the answer in the right-hand space so that the next question can be written there.

6) Read the next question, answer it, and continue as in steps 1, 2, 3, 4, 5. Keep on until you have answered all the questions. Do not skip any, write "DK" if you do not know the answer to a question.

Do not ever force the machine. If you encounter any difficulty at any time, call the experimenter immediately.

When you have answered all the questions, the machine will present again all those questions which you did not answer correctly the first time. Re-answer these, proceeding as before (steps 1-6). Be sure to number each one of your questions with the number of the question it goes with.

Questions you do not answer correctly will continue to appear in the left-hand window. Eventually, when you have answered all the questions correctly, the same question will keep appearing in the question space every time you lower and raise the handle. You have then completed the set of questions and you will call the experimenter.

3. Introduction to Experiment

The experiment which you have consented to become a part of is being conducted under the auspices of the U. S. Navy. It is an important investigation and we wish to thank you for the time that you are willing to devote in helping us make this study.

The study is related to the use of Teaching Machines. You may have read about them in one of the many articles that, during the past two years, have appeared in magazines and newspapers. The purpose of the machine is simply to present you with a body of material, broken down into units, to be learned.

The following is required of you:

1. 4 to 5 hours of your time (2 hours. scheduled)

2. Fill out the attached questionnaire and hand it to the experimenter when you come for the 1st hour.

3. Carefully read the attached instructions. They will be covered by the experimenter, who will be glad to answer any of your questions.

4. Carefully read and study the attached sheets entitled: "Pre-Learning Material."

You will be reimbursed for the total number of scheduled hours you spend on the project.

Report to Rm. _____ 4th Floor, Ingersoll Bldg. at ______.

Thank you again for your time and energy. You are rendering an important service to your college, community and fellow students.

4. Instructions

The material you are about to be confronted with in this experiment is in no way a test of your intelligence or abilities. We are in the process of gathering information relative to the use of a machine for presenting material to be learned. You will use one of these machines to learn a body of material on a particular subject. No prior knowledge of the subject is required or expected.

WHAT YOU WILL SEE AND USE.....

The learning box has two windows. The one toward the center will show the question you are to answer and then the answer to the question after you have tried to answer the question. You will write your answer in the window off to the right. An answer must be given in all instances! Always write the number of the question on the slip. Write the letters "D.N." for "don't know" when appropriate. Try always to answer the question to the best of your ability.

You will be given detailed instructions on the use of the machine by the experimenter.

A FEW DON'TS.....

1. Do not touch any button, knob or lever on the box until directed to do so and under the supervision of the experimenter.
2. Handle the boxes when allowed to do so, very carefully.
3. When you do use the handle on the machine move it slowly and gently. (Do not force anything - call the experimenter immediately if you encounter any difficulty.

YOU ARE REQUIRED TO.....

1. Read the question and then answer it on the blank paper in the window. You are required to supply the missing word or words. A multiple of words is represented by a vertical line dividing blank space.
2. Answer all questions. Write in the number of the question and "D.N." when appropriate.
3. Reanswer questions you did not get correct the first, second, third time,etc. (You will be given explicit instructions on how to operate the handle so that question you do not answer correctly will continue to appear in the window until you answer them correctly.)

OPERATION OF HANDLE.....

Raise handle and push handle to the right when your answer is right.
Raise handle and lower handle when your answer is wrong.

Remember...push to right when right. Do not push to right when wrong.

If at any time something appears to be wrong with the machine...call the experimenter.

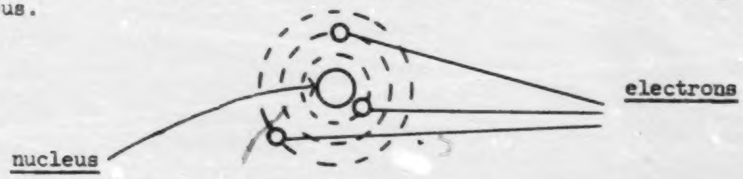
5. PRE-LEARNING MATERIAL

This is preliminary background material to the material to be learned through the teaching machine. Some of the attached material may already be familiar to you. You may know more details of the subject than is included here. However, a lot of information has been compressed into the brief space of these few pages. Therefore, please study the material carefully. You will be asked to take a brief quiz covering the contents before proceeding with the experiment.

- - - - - - - - - - - -

All the effects of electricity can be explained and predicted by assuming the existence of a tiny particle called the electron.

WHAT IS THE ELECTRON -- All substances and materials are composed of small particles called atoms. These atoms in turn consist of electrons revolving in orbit around a nucleus.



THE ATOM

Each source of electricity is produced principally in the same way; by forcing electrons out of their normal orbits in the atom, thus creating "free"electrons. To force electrons out of their orbits, some kind of energy is required. One source of such energy arises from chemical action. In this case we call the source of electrical force, a battery.

There is in nature a physical law which compels free electrons to seek out a place where there is a lack of electrons, and to move there. However, there must be a path along which they can flow. This path can be provided by a piece of wire, or some other material. The essential point is this: if we have an accumulation of free electrons at one place and a lack of electrons at some other place, and provide a path between the two, electrons will flow. This flow of electrons is called an electrical circuit. It should be borne in mind that circuit implies not only a complete path, but also the existence of an excess and lack of electrons in the path.

Electrical current is the flow of free electrons. Just as "gallons per minute" is the standard measure for indicating water flow, so the "ampere" is the standard measure for indicating the number of electrons that flow past a given point in a second. Amperes is therefore the unit in which electric current is measured.

To move any object - solid, liquid or gas - you must put pressure or force behind it. In just the same way you must apply a force - an "electromotive" force - to cause electrons to move. Electrical pressure or force is measured in "volts" and is called electromotive force. A battery is a source of electromotive force; that is, the battery has chemically built up a difference between excess of electrons in one place and lack of electrons in another, and is able to maintain this difference over a period of time. Then, when a battery is "hooked up" it will "push" electrons through the ~~material~~ the wire (the wire) which forms the electrical circuit.

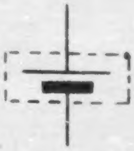
Resistance is a measure of how easily a material gives up from electrons. In a sense then, a material will oppose the flow of electrons through it, depending on how tenaciously it clings to its free electrons. Every type of material exerts some opposition to current flow, whether large or small, and this opposition is called "resistance". For example, metal wire "gives up" electrons easily and therefore offers little resistance to the flow of electrons. In contrast, rubber does not give up electrons easily and offers a substantial resistance to the flow of electrons. The standard for measuring the degree of resistance of a material is called the Ohm.

6. SUMMARY

I Electric circuit. A completed electric circuit requires that two conditions be present: 1) A continuous path for the flow of electrons and 2) a source of electromotive force. In the absence of either condition, a circuit does not exist.

II Components of an Electrical Circuit.

A. Electromotive force
  1. Electromotive force (abbreviated EMF) is the pressure applied which forces electrons to flow; A battery is an example of a source of EMF.
  2. Unit of measurement: Volt
  3. The symbol representing EMF in a formula: E
  4. The symbol representing EMF in a diagram:
     Note: Long line represents the excess of electrons
     Short line represents the lack of electrons
     Together they represent the battery



B. Current
  1. When EMF is applied in a circuit, the electrons will all start flowing in the same direction: from the excess of electrons to the lack of electrons. This flow of electrons is called "current". Current signifies not only that electrons are flowing, but also how many are flowing past a given point in one second.
  2. Unit of measurement: Ampere.

3. The symbol representing current in a formula: I

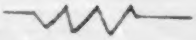
4. The symbol representing current in a diagram:
(an arrow).

C. Resistance

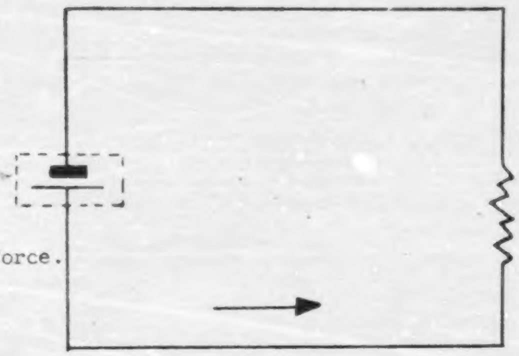
1. Resistance (R) is the opposition to the motion of electrons in a circuit.

2. Unit of measurement: Ohms.

3. The symbol representing resistance in a formula: R

4. The symbol representing resistance in a diagram: 

D. Components represented as a schematic drawing:


I or current.
BATTERY
R. or resistance.
Source of
E. or
electromotive force.

Arrow indicates direction of current flow.

7. Pre-Learning Quiz

NAME ______________________

DATE ______________________

Please answer the following questions:

1. When _____ flow in a circuit you have what is known as electrical current.

2. The direction of current flow is from the _____ of electrons towards the _____ of electrons.

3. A battery is a source of _____ force, that "pushes" electrons through a circuit.

4. The standard measure for indicating current is the _____.
The standard measure for indicating electromotive force is _____.
The standard measure for indicating resistance is the _____.
The standard measure for indicating resistance is the _____.

5. In terms of electrical circuits, an electric light bulb or a toaster are examples of a _______. They oppose the flow of current depending upon the ease with which they give up _____.

6. An electrical circuit must contain two things 1) a continuous path for the _____; 2) a source of _____.

DIAGRAM

Indicate on the diagram the direction of current flow.

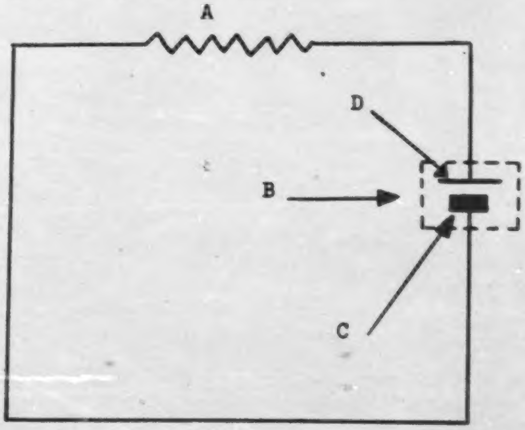
Identify in the diagram:

7. A

8. B

9. C

10. D



8. PROTOCOL

Name:________________________.

1. Do you think you learned anything?

2. How much of this material did you already know? What % in your estimation?

3. Was this basically a review or was it new learned material?

4. Do you think you will be able to retain the material you learned in this fashion?

5. Was there anything about any of the questions or all of the questions that helped you get the answers?

6. Did you often guess the answers?

7. Do you think the material followed a logical sequence or jumped around?

8. Were all the questions a "give-a-way" or did you have to puzzle some of them out?

9. Do you like using the learning machine? Would you choose to study on your own in this way?

10. Would you like to see such machines replace teachers?

11. Do you think the machines are a good or a bad substitute for a teacher? Why?

12. Do you have any other comments on any aspect of the material in the machine or on the machine itself?

THE MATERIAL ON THIS SHEET WILL REMAIN STRICTLY CONFIDENTIAL.

APPENDIX N

Correlation Between the Electrical Term and Symbol Index and the Pre-Treatment Examination Scores.

A correlation of r - .622 was found to exist between the number of electrical terms and symbols checked off by Ss on the questionnaire, as terms or symbols with which they were familiar and scores on the pre-treatment examination.

r - .497 to r = .721 are the fiducial correlation limits for the obtained correlation of .622 at the 5% level.

APPENDIX N

Correlation between Learning Efficiency and Performance Gain For Machine and Prompting Card Groups

A correlation of $r = -.022$ was obtained between the number of responses to complete a "no-error" run and performance gain.

A *t* test of the obtained r indicated that it docs not differ significally from zero.

APPENDIX N

Correlation Between Attitude to the Teaching Machine and Performance Gain

A correlation of $r = -.16$ was obtained between Ss scores on the protocol, a measure of Ss attitude to teaching machine and Ss performance gain.

A *t* test indicated that the obtained r is not significantly different from a correlation coefficient of zero.

APPENDIX N

Comparison of Machine and Prompting Card Pre-Treatment Examination Means to Determine Relative level of Naivete.

Table 34

Pre-Treatment Examination Means

		Teaching Machine		Prompting Cards	
		Completion	Multiple Choice	True-False	Completion
Order of Presentation	Random	19.50	10.00	12.50	17.90
	Sequential	17.20	13.10	14.10	15.80
Type of Item	Mean	18.35	11.55	13.30	16.85

An analysis of variance yielded a between type of item F ratio significant at the .01 level of confidence as shown in Table 35.

Table 35

Analysis of Variance of Pre-Treatment Examination Scores for Type of Item.

Source of Variation	df	MS	F
Between	3	196.25	6.59**
Within	76	29.79	
Total	79		

** .01 level of significance

Table 36

Comparison of Pre-Treatment Examination
Means for Type of Item

	Teaching Machine			Prompting Cards
	Completion	Multiple Choice	True-False	Completion
Completion (Machine)		3.95**	2.94**	.87
Multiple Choice			1.02	3.08**
True-False				2.06*

** .01 level of confidence.
* .05 level of confidence.

Comparison of Text, Lecture and Machine
Pre-Treatment Score Means to determine
Relative Naivete.

Table 37

Pre-Treatment Examination Means

	Machine	Lecture	Text
Mean	14.48	17.17	11.65

Table 38

Analysis of Variance of Pre-Treatment Examination Scores

Source of Variation	df	MS	F
Between	2	215.84	6.01**
Within	117	35.90	
Total	119		

** .01 level of significance

Table 39

t test Comparison of Machine, Lecture and Text Pre-Treatment Examination Means.

	Machine	Lecture	Text
Machine		2.20*	1.81
Lecture			3.37**

** .01 level of confidence.
* .05 level of confidence.